COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

October 1957

Edward F. Barrett Station, Long Island Lighting Co., recently dedicated addition to the system's generating capacity

Engineering Modern Incinerators

World Power Data

Split Pumps Vs Single Pumps

Power From the Sun

Kellogg's Fabricating Abilities Keep Pace

Culminating many months of intensive work with Philadelphia Electric Company, including the testing and evaluation of numerous alloys, M. W. Kellogg is now fabricating the 2,400 ft. of main steam piping, which it will also install, for Eddystone Station Unit No. 1.

Piping is made of Type 316 Stainless, designed for use at 5,000 psi-1,200 F. at the turbine throttle. Calculated minimum wall equals 2.344 in. from Boiler to Sulzer Stop Valves (8 leads), 2.188 in. from Sulzer Stop Valves to Mixing Header (8 leads), and 2.656 in. from Mixing Header to Turbine (4 leads).

Kellogg's ability to handle the exacting task of bending, welding, heat treating, and testing such huge amounts of heavy-walled pipe to close schedules is a major reason for the company's long-standing reputation in the industry.

The M. W. Kellogg Company welcomes the opportunity to discuss its complete power piping design, fabrication, and installation facilities with consulting engineers, engineers of power generating companies, and manufacturers of boilers, turbines, and allied equipment.

M. W. Kellogg has developed many welding techniques for the fabrication of high alloy steam piping, including K-Weld*. With this unique technique of arc welding, the pipe interior is under controlled inert gas pressure—assuring complete root bead penetration and a highly uniform internal contour without the use of backing rings.

FABRICATED PRODUCTS DIVISION

THE M. W. KELLOGG COMPANY, 711 THIRD AVENUE, NEW YORK 17, N. Y.

A SUBSIDIARY OF PULLMAN INCORPORATED

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POWER PIPING—THE VITAL LINK

*Trademark of The M. W. Kellogg Company

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERERATION

Vol. 29 **No. 4**

October 1957

Feature Articles

Editorials

Departments

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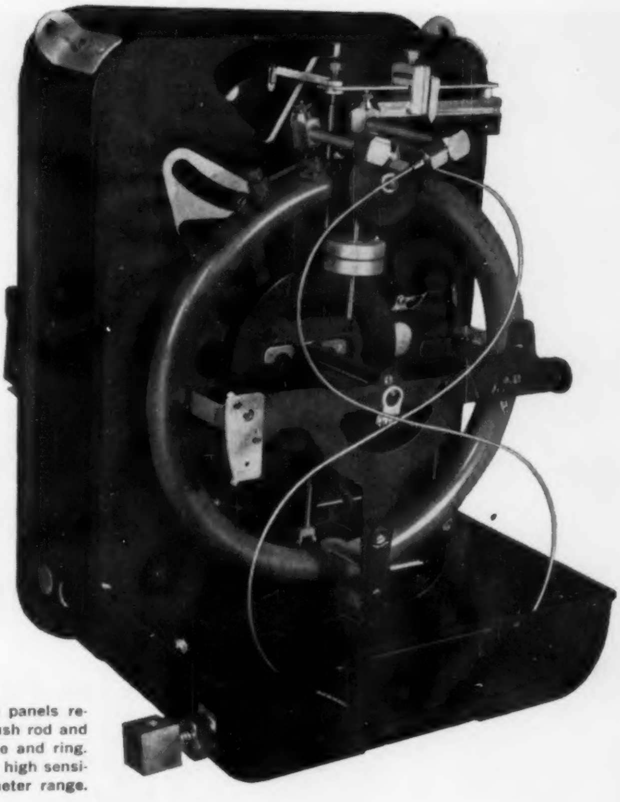
BPA

Printed in U. S. A.

HAGAN RING BALANCE FEATURES—NO. 2

SAFE SENSITIVE METERING at 2500, 6000, 15000 PSIG



Rear of Ring Balance Meter with side and top panels removed to show S-tube arrangement. Note the push rod and resistant spring assembly, visible back of S-tube and ring. This feature of the Ring Balance makes possible high sensitivity at low flows and simple adjustment of meter range.

No question about it. The cylindrical tubing used to form the ring and S-tubes of the Hagan Ring Balance meter is the safe, sure means for containing high pressures. There are no gaskets or stuffing boxes to leak, blow out, bind or otherwise spoil this ideal design.

Pressure impulses are brought from the meter terminals to the ring through solid-wall S-tubes which, because of their special configuration and metal-to-metal fittings, provide safe, completely flexible connections and preserve the inherent high sensitivity of the meter.

New, rigid, weatherproof, die-cast, aluminum case. Four-piece back for complete accessibility.

Check these other Ring Balance features with your local Hagan office

1. High sensitivity at low flows due to unique range calibration system.
2. Ease of calibration under operating static pressures with factory-calibrated check weights. No more four-story water columns and telephones.
3. Sealing fluid density and level not critical. No eye-droppers required.
4. Interchangeable ring assemblies for full scale ranges from 0.5″ w.c. to 560″ w.c. Adjustment on any one ring over a 7:1 differential range.
5. Wide range computation and/or compensation by means of built-in, easily checked mechanisms available on most models.
6. Pneumatic or electric transmission also available.

Bulletin MSP-141 describes these features and the new design of the Hagan Ring Balance meter case. ASK US FOR IT.

HAGAN CHEMICALS & CONTROLS, INC.

HAGAN BUILDING, PITTSBURGH 30, PENNSYLVANIA
DIVISIONS: CALGON COMPANY, HALL LABORATORIES
IN CANADA: HAGAN CORPORATION (CANADA) LIMITED
OFFICES IN: MONTREAL, TORONTO, VANCOUVER, EDMONTON

Pinehurst

tees off on fuel costs

Golfing resort cuts costs 33% with modern burning of coal

The central power plant at the famous golfing resort of Pinehurst, N. C., has to furnish a reliable supply of steam to three hotels and seven other buildings.

When Pinehurst recently decided to modernize power facilities, the consulting firm of Wiley and Wilson, Richmond, Va., was called in to study the situation. Since coal cost approximately 40% less than the nearest competitive fuel, the final decision called for burning coal the modern way. Today two new automatic stoker-fired boilers (only one of which is operated at a time) replace four 150-HP hand-fired boilers. Combustion control is automatic; coal and ash handling is greatly simplified. And now, according to management, "the cost of generating steam is 33.4% less than with the old plant."

Facts you should know about coal

Not only is bituminous coal the lowest-cost fuel in most industrial areas, but up-to-date coal burning equipment can give you 10% to 40% more steam per dollar. Today's automatic equipment can pare labor costs and eliminate smoke problems. And vast coal reserves plus mechanized production methods mean a constantly plentiful supply of coal at a stable price.

Technical advisory service

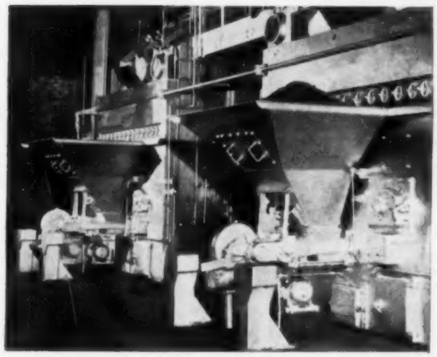
The Bituminous Coal Institute offers a free technical advisory service on industrial fuel problems. If you are concerned with steam costs, write to the address below. Or send for our case history booklet, complete with data sheets. You'll find it informative.

Consult an engineering firm

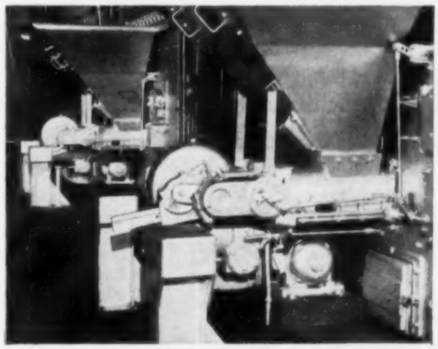
If you are remodeling or building new heating or power facilities, it will pay you to consult a qualified engineering firm. Such concerns—familiar with the latest in fuel costs and equipment—can effect great savings for you in efficiency and fuel economy over the years.

BITUMINOUS COAL INSTITUTE

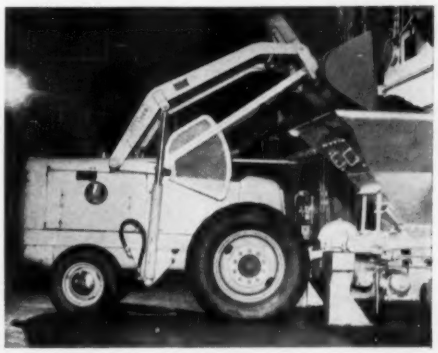
Southern Building • Washington 5, D.C.



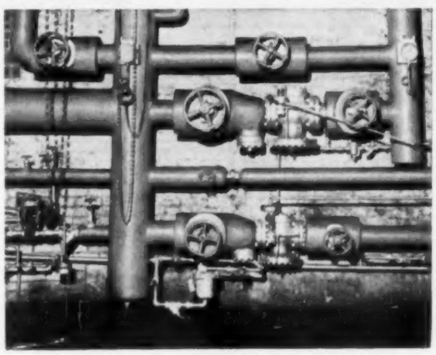
Two Babcock & Wilcox type FF integral-furnace boilers supply all the steam for Pinehurst at about 125 pounds pressure at 600° F. Average steam load is 11,000-12,000 pounds per hour per day.



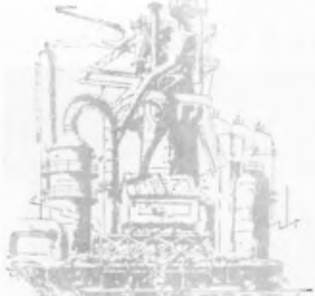
Close-up of stokers. These underfeed, single retort, side-dump models are made by Detroit Stoker. They operate automatically, each driven by a 3 HP enclosed motor.



Frank G. Hough Payloader transfers coal from railroad trestle to storage, from storage to stokers. Payloader also facilitates handling of ash disposal.



Readily accessible, all of the steam distribution lines are taken off a manifold in the engine room. Five separate lines with Ruggles-Klingemann automatic pressure regulators distribute the steam at the required pressure in each case.



First in water conditioning

Cochrane HOT PROCESS
AT U. S. STEEL'S CLAIRTON PLANT

Designed to soften and deaerate 100,000 GPH of boiler feed water, this Cochrane unit at U.S. Steel's plant is a sludge blanket design deaerating type Hot Process Softener with a 38' dia. spherical top sedimentation tank. The Softener is followed by six 11' dia. anthracite filters equipped with surface washers.

Cochrane pioneered the versatile Hot Process Softener. Its flexibility and efficiency are unquestioned and it provides a water softening process that can handle both turbid surface supplies and clear well waters.

Cochrane Hot Process Softeners can be used to reduce silica economically and effectively. It is also possible to provide integral deaeration elements for condensate and treated makeup where required.

For medium and high pressure boilers, Hot Process can be followed by Hot Zeolite to provide zero hardness and lower solids as well as to reduce CO_2 in the steam.

If you now have a Hot Process Softener, Cochrane Hot Zeolite may be readily added, assuring higher effluent quality at lower treating cost.

Cochrane, first in water conditioning for over half a century, continues to lead the way in Hot Process and Hot Zeolite. Call our engineers for the answer to your problem. Ask for Publication 4801.

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Demineralizers • Zeolite Softeners • Hot Process Softeners • Hot Lime Zeolite Softeners • Dealkalizers • Reactors • Deaerators • Pressure Filters
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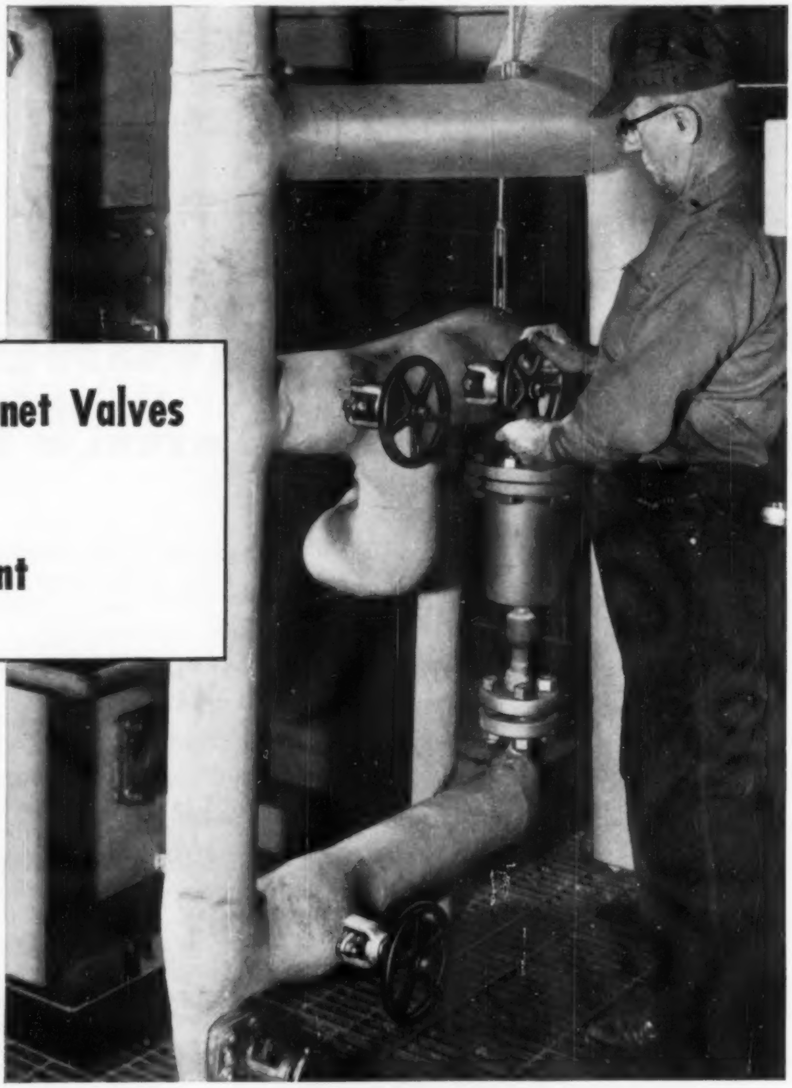
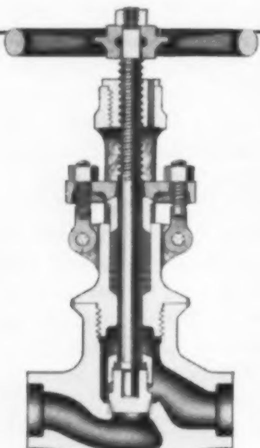
Ad. 2.01

Newest Design in Small Steel Globe, Angle and Check Valves

Crane Lip Seal Bonnet Valves
(patented)
Save Money for This Power Plant





Central Illinois Electric & Gas Co.'s experience with Lip-Seal valves is typical. Since 1952, this patented Crane small steel valve design for high-pressure/high-temperature service has saved this utility many dollars.

Shown is a 3-valve installation at Sabrooke Station in Rockford on 900 psi steam lines to the ash removal system. In more than 5 years on this tough service, none was given more than minimum routine maintenance—never any attention to bonnet joints.

On other severe services as well, the plant is aware of the continuous good performance and easy care of Lip-Seal valves. More are being installed as other makes give out.

Lip-Seal design features a strong, nonfreezing screwed bonnet joint that holds pressure load, with a peripheral weld for tightness only. Weld grinds off easily and repeatedly without damaging joint.

Improved disc-stem connection minimizes vibration . . . provides pilot guiding for the disc. Stellite seating surfaces withstand temperature, corrosion and erosion. Globe, angle and check patterns; 1500- and 2500-pound classes. Sizes ½ to 2 inches. Get full information from your Crane Representative.

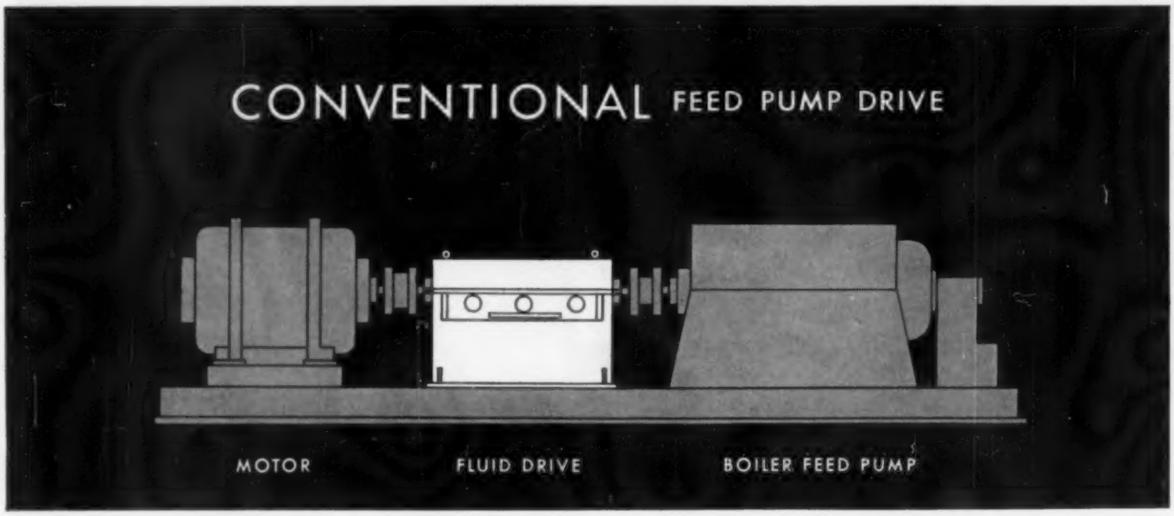
Literature on Lip-Seal valves supplied by your Crane Man, or write to address below.

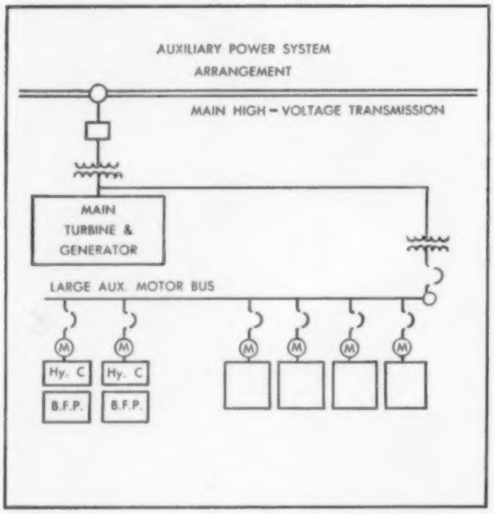
CRANE VALVES & FITTINGS

PIPE • PLUMBING • KITCHENS • HEATING • AIR CONDITIONING

Since 1855—Crane Co., General Offices: Chicago 5, Ill., Branches and Wholesalers Serving All Areas

How Gýrol® Fluid Drive meets all

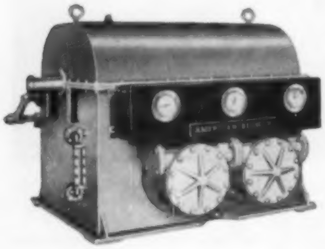




Of all power-plant auxiliaries, the boiler feed pump consumes the greatest single segment of invested power. To release more of this power to consumer lines, power plants of all sizes are controlling feed water flow by speed regulation through Gýrol Fluid Drive – driven by a constant speed prime mover.

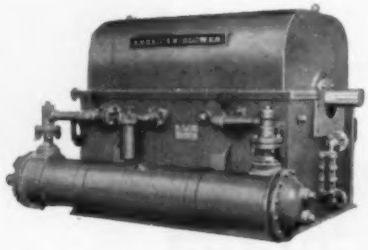
Gýrol Fluid Drive offers several specific advantages:

1. It saves power over the entire operating range by eliminating wasteful throttling by valves.
2. Fluid Drive's adjustable-speed feature permits reduction in pressure – resulting in further power savings.
3. It reduces wear on bearings, and other vital pump parts, by letting the pump operate at speeds that fit boiler demands.
4. With Fluid Drive, paralleling of pumps is simplified. Change-over from operating to standby pump is quick and easy.
5. Quiet operation is inherent in the design of Fluid Drive, since a "cushion of oil" is the means of energy transmission.



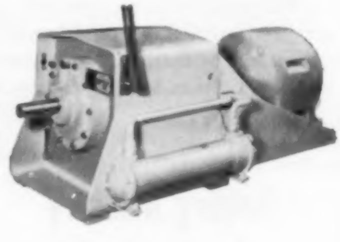
TYPE VS CLASS 6

- adjustable speed control
- 250 to 12,000 horsepower
- speeds to 3600 rpm



TYPE VS CLASS 4

- adjustable speed control
- 100 to 2500 horsepower
- speeds to 1800 rpm

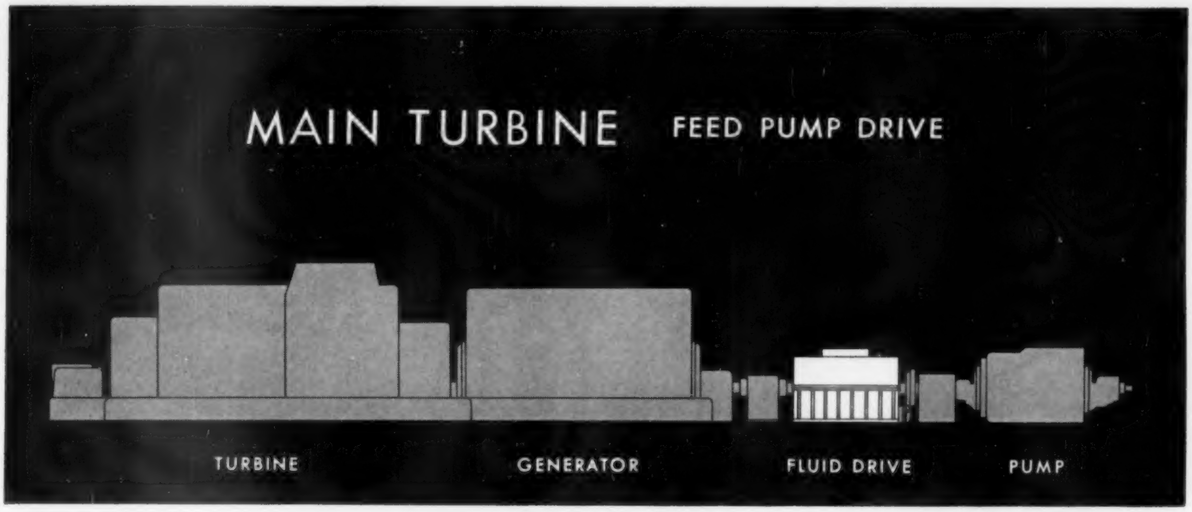


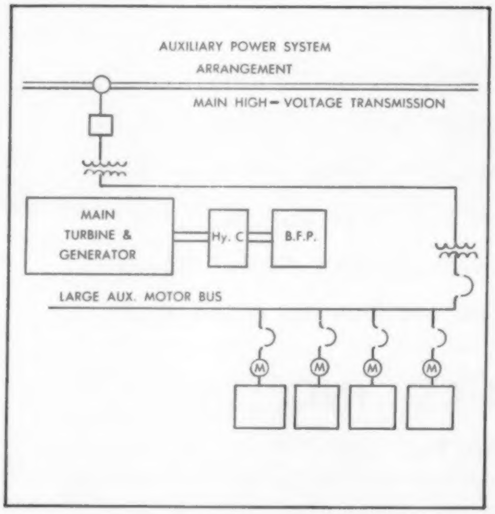
TYPE VS CLASS 2

- adjustable speed control
- 1 to 800 horsepower
- speeds to 1800 rpm

requirements for feed pump control

Regardless of station size, arrangement, or prime mover, you get the advantages of power savings, reduced pressures, and quiet operation with American Blower Gýrol Fluid Drives





Already in the construction stage is the use of Gýrol Fluid Drive for main turbine feed pump drives on some of the largest generating units yet projected.

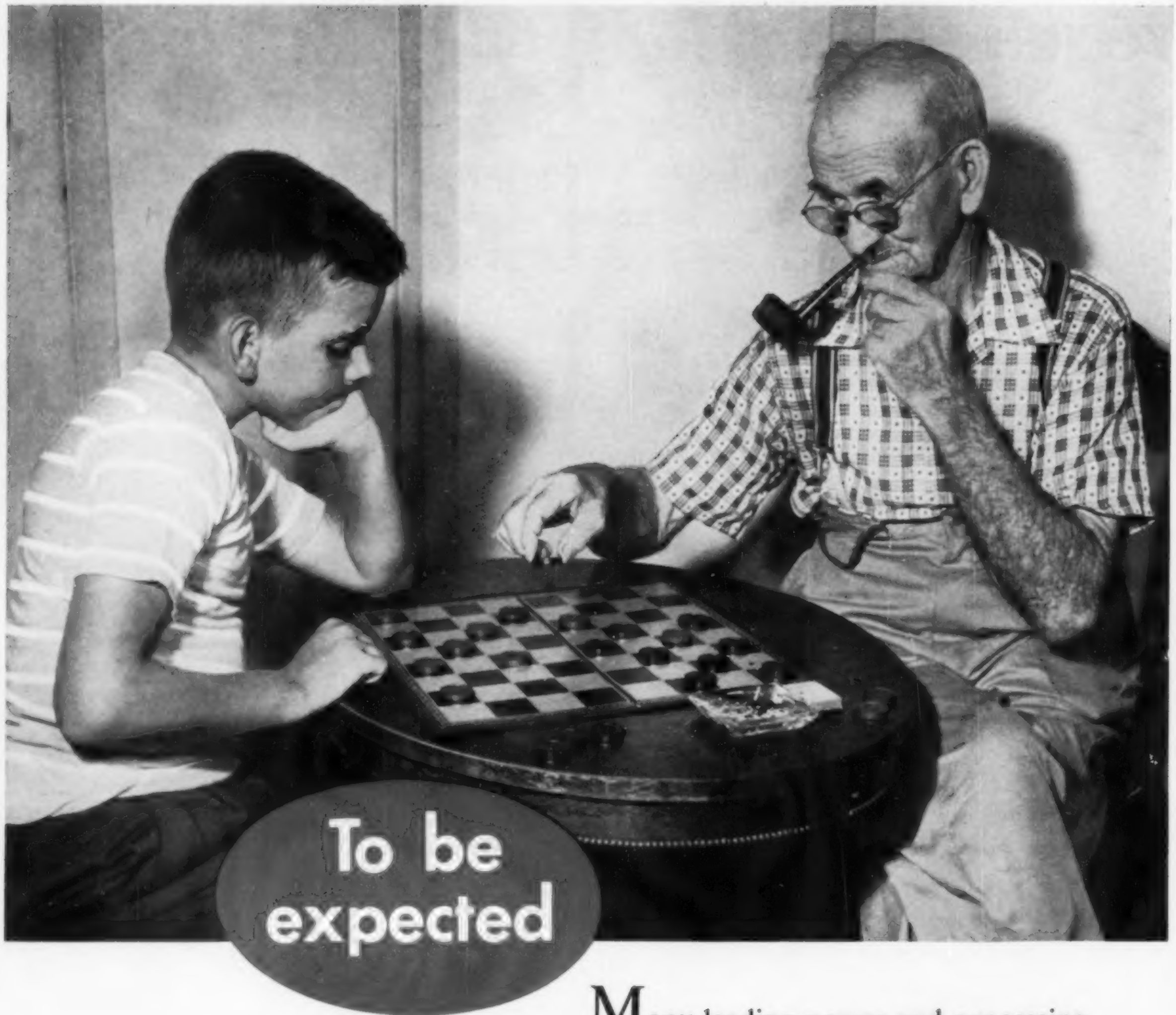
For example, two of these stations will each drive, through a 12,000-hp adjustable-speed Gýrol Fluid Drive, the main feed pump from the high-pressure turbine. Full boiler capacities will be supplied by the single 5-stage pump, each delivering 6330 gpm against 6400 feet total discharge head when operating at 3510 rpm with feed water at 363° F.

Each pump requires an excess of 11,000 hp, and will be driven from the generator shaft through an adjustable-speed Gýrol Fluid Drive.

In your plans for expansion, why not discuss the advantages of Gýrol Fluid Drive with an American Blower engineer. His knowledge of this application in modern power plants may prove valuable to you. Call our nearest branch, or write: American Blower Division of American-Standard, Detroit 32, Michigan. In Canada: Canadian Sirocco products, Windsor, Ontario.

AMERICAN BLOWER

Division of American-Standard



Many leading power and processing plants continue to call on Mitchell for prefabricating and erecting high-temperature, high-pressure, special-process piping. They do so not solely on the basis of shop facilities but because they have learned that specialized experience pays off. On your next critical piping job, for the sake of economy, permanent safety and general satisfaction . . . ask us in.

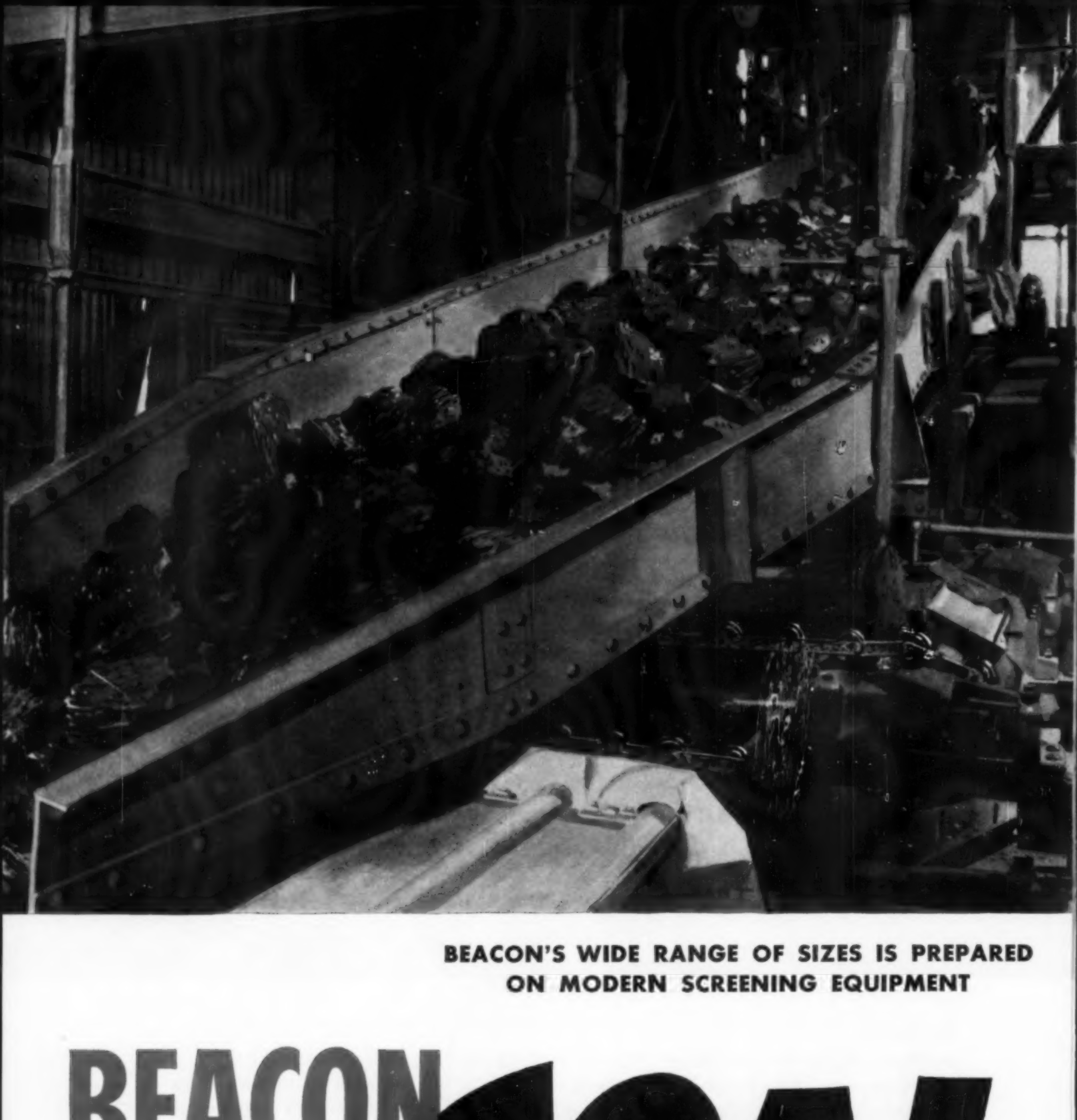
W. K. MITCHELL & CO., INC.

Philadelphia 46, Pa.

WESTPORT JOINT
(PATENTED)

MITCHELL PIPING
SINCE 1899

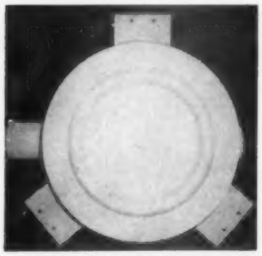
PIPING FABRICATORS AND CONTRACTORS



PROGRESS IN POWER through PROGRESS IN HEAT TRANSFER EQUIPMENT

FIRST ALL-WELDED FEEDWATER HEATERS

Workman welding copper-nickel tubes to foot-thick steel tube sheet with 140-monel electrodes. Under destructive testing, rolled joints and tubes welded with cupro nickel rods leaked at elevated pressures, but tubes welded with 140-monel electrodes were leak-proof at 9600 psi.



End view showing torus ring welded to channel and channel cover. Access to head is obtained by cutting ring with special tool; torus ring can be re-used. Conventional split key ring assembly taking the load on the cover is retained.

▶ A few years ago, an all-welded feedwater heater for 3600 psi and 790F would have been called a fantastic dream.

Yet six all-welded feedwater heaters in this pressure-temperature range are now proving their worth in the Linden, N. J., Generating Station of the Public Service Electric and Gas Company. Designed and manufactured by the Yuba Heat Transfer Division, formerly the Heat Exchanger Division of The Lummus Co., these heaters represent one of the many "firsts" contributed by this organization to the progress of the power industry.

In the heater shown above, two 50-inch-diameter cylinder sections of 1⅛-inch carbon steel were welded together. The open ends of the U-bends are welded, not roller-expanded, into the tube sheet (see upper small photo). Heads are sealed by a steel torus ring welded to channel cover and channel (see lower small photo).

The all-welded design minimizes the leakage which occurs in the conventional bolted and gasketed construction under high temperatures and pressures. Results are reduced maintenance and downtime.

This all-welded construction has been so successful it is certain to be specified for practically all future installations. Yuba engineers would be pleased to work with you. Call on them.

YUBA

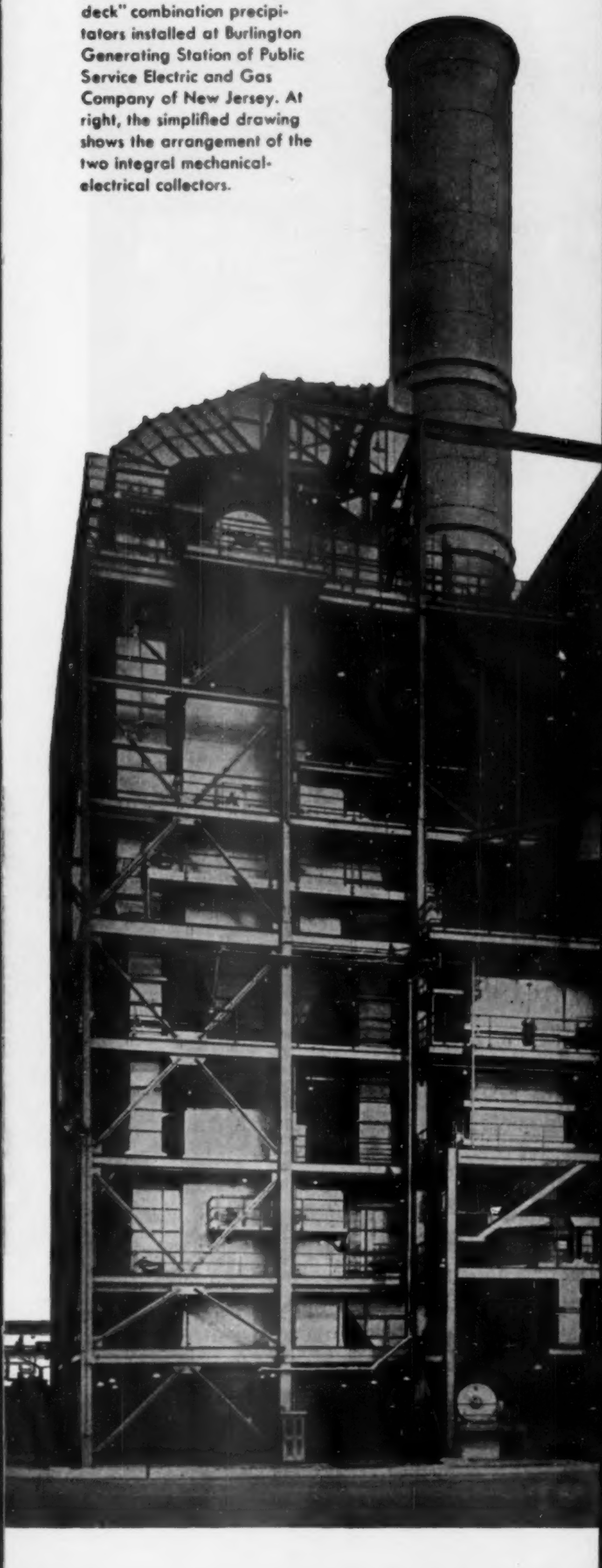
CONSOLIDATED INDUSTRIES, INC.

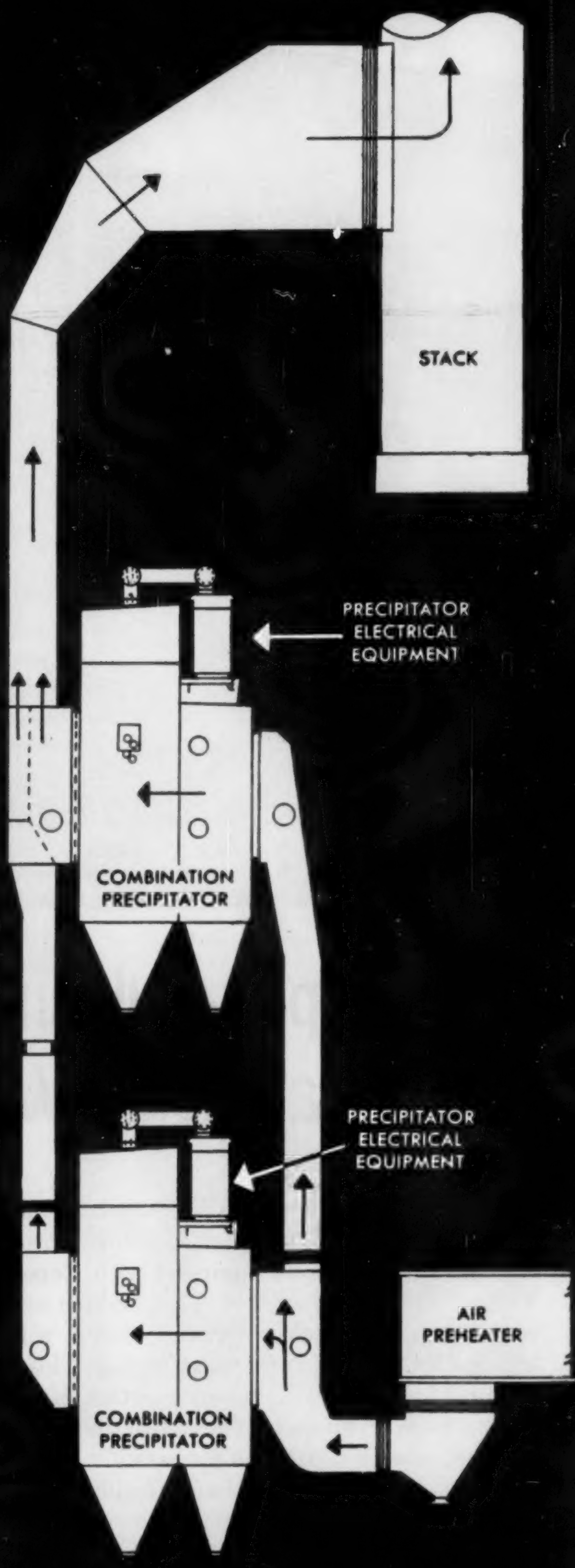
Other Divisions Manufacturing Heat Transfer Equipment
California Steel Products Division, Richmond, Cal.
Adsco Division, Buffalo, N. Y.

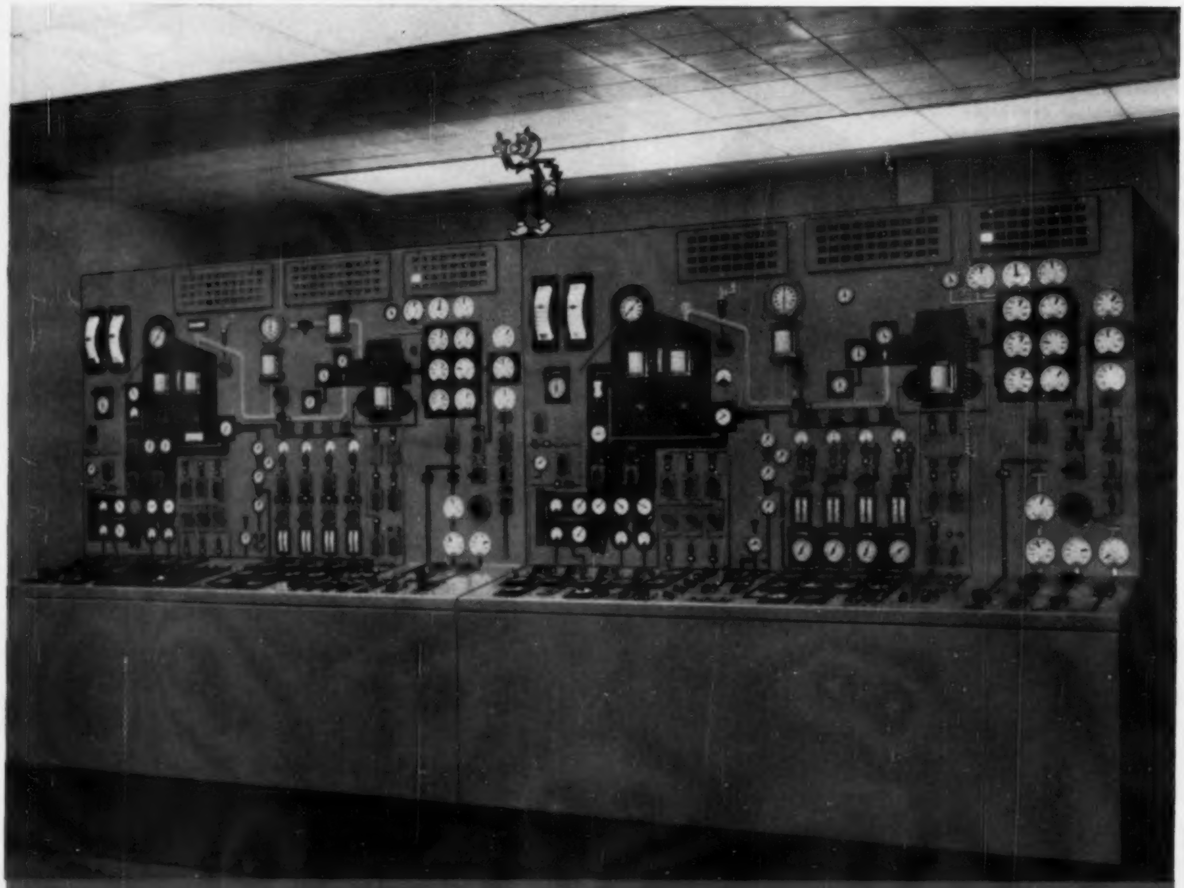
YUBA HEAT TRANSFER DIVISION
HONESDALE, PENNSYLVANIA
NEW YORK SALES OFFICE: 530 FIFTH AVENUE
REPRESENTATIVES IN PRINCIPAL CITIES

STEAM SURFACE CONDENSERS • EVAPORATORS
STEAM JET REFRIGERATION • STEAM JET AIR EJECTORS
FEEDWATER HEATERS • BAROMETRIC CONDENSERS

Research-Cottrell's "double-deck" combination precipitators installed at Burlington Generating Station of Public Service Electric and Gas Company of New Jersey. At right, the simplified drawing shows the arrangement of the two integral mechanical-electrical collectors.







The Louis V. Sutton Plant uses centralized control for each unit. All instruments are of the miniature type, permitting a reduction in size of panel. Engineers and constructors: Ebasco Services, Incorporated.

It's Copes-Vulcan Combustion Control at Louis V. Sutton Plant!

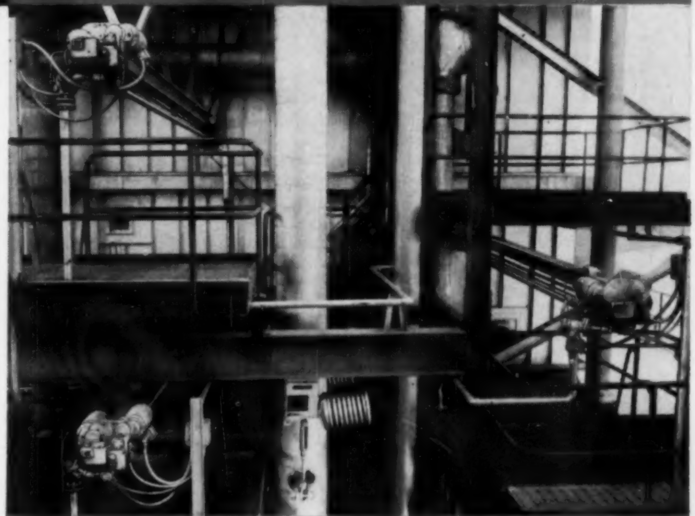
Units 1 and 2 in the Louis V. Sutton Steam-Electric Generating Plant of Carolina Power & Light Company are equipped with Copes-Vulcan combustion control. This modern system features simplicity of circuit design, with independent control loops on air flow, fuel loading and furnace draft. Interconnection of the control loops is eliminated because of the speedy response of each of the components.

Station and controller design facilitates remote switching from automatic to manual, or manual to automatic. Variations in circuit design would provide for shortening tubing runs between controllers and drive units, valves or other controlling devices, should transmission lines become excessively long.

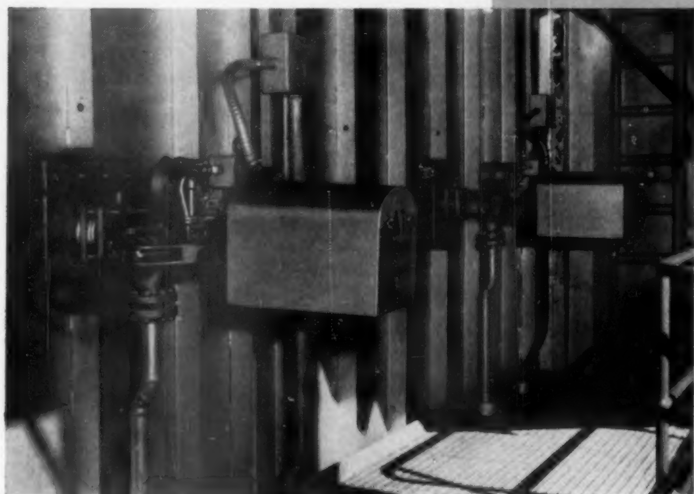
Modern Copes-Vulcan combustion control systems offer many advantages that will help you reduce production costs. In addition, from this one dependable source, you can get a fully integrated system including feed water control, boiler feed pump recirculation control, steam temperature control and automatic soot blowing. Your Copes-Vulcan representative has the ideas, information and experience to help you choose the system best suited to your needs.

C-V NEWS NOTES

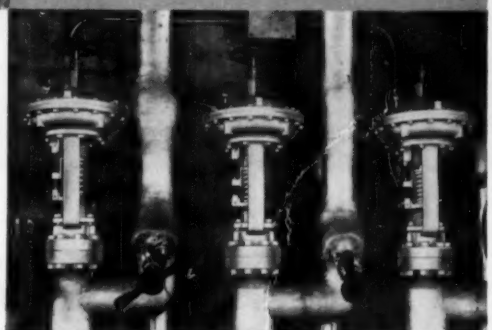
For a complete description of the Sutton Plant control system, see your Copes-Vulcan representative, or write the factory for Bulletin 1032.



Vulcan long retractable soot blowers are installed on Units 1 and 2. Both soot blowing systems feature automatic-sequential control.



Copes-Vulcan RW-2E wall de-slaggers on Unit 2 have dual-motor electric drive. One motor extends and retracts the lance, the other rotates the nozzle.



Copes-Vulcan boiler feed pump recirculation valves on Units 1 and 2 open automatically when water flow falls below a pre-determined minimum. When flow reaches a predetermined maximum controller closes the valve.

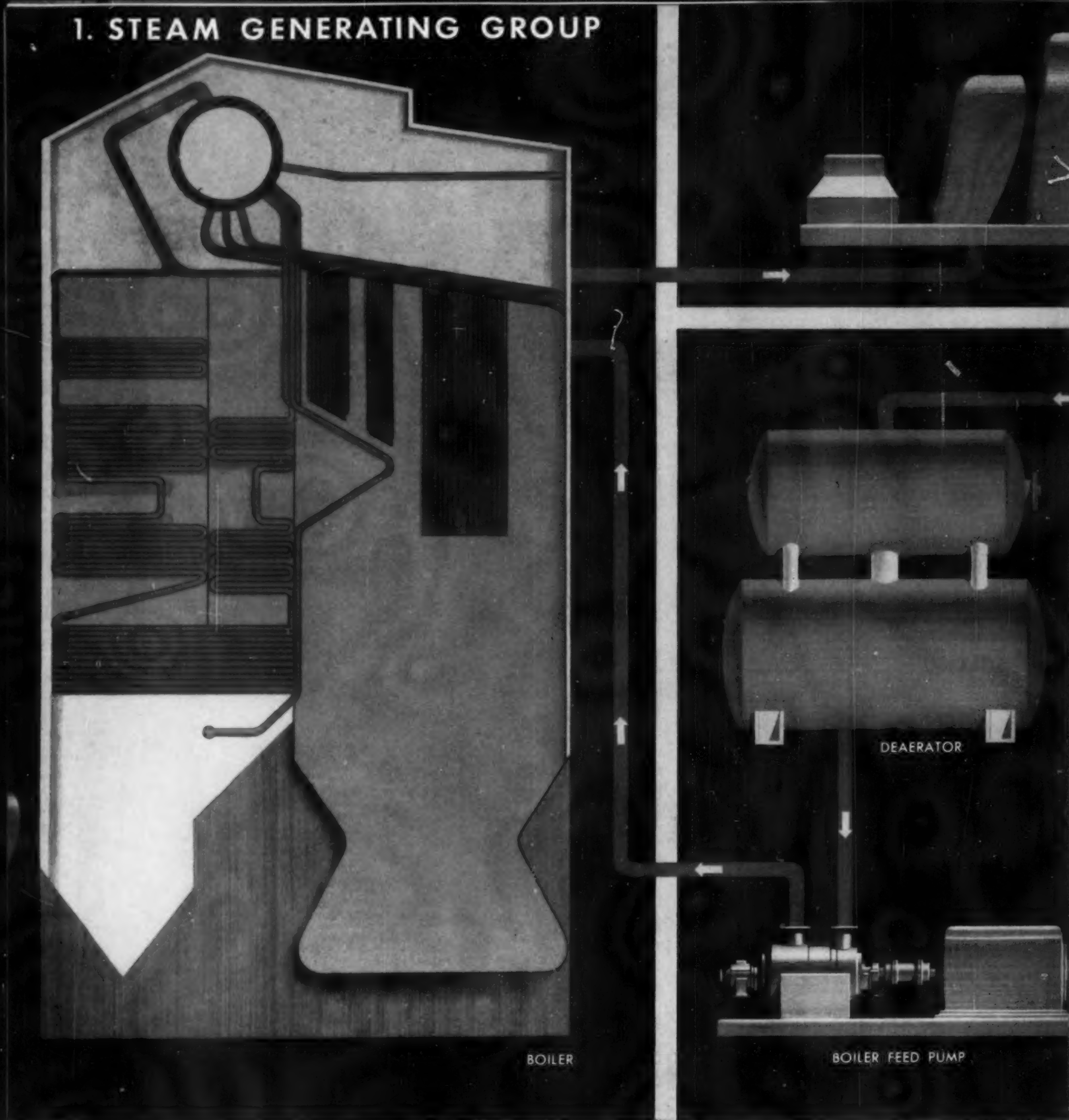
COPES VULCAN

BLAW-KNOX

COPES-VULCAN DIVISION

BLAW-KNOX COMPANY

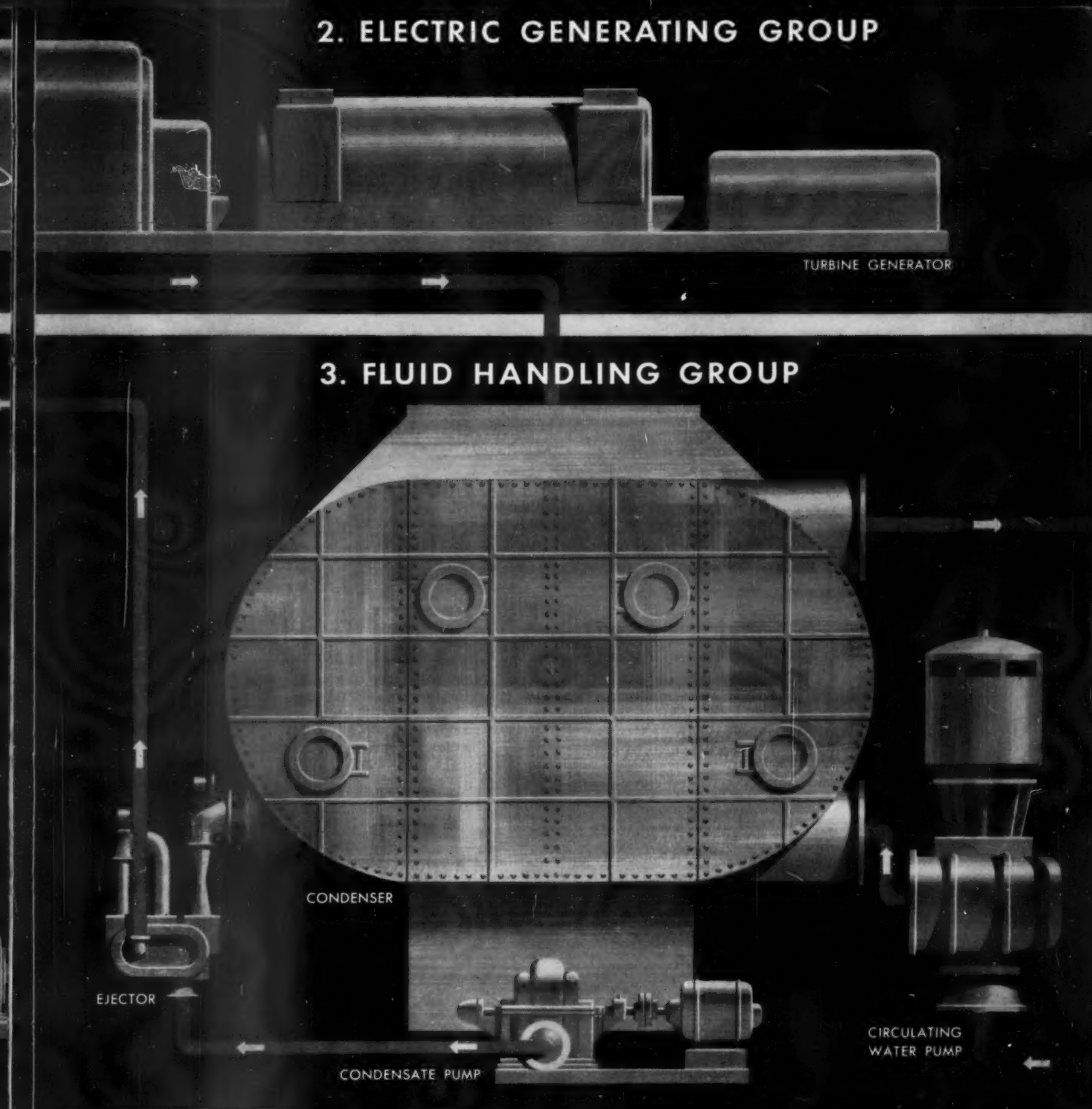
ERIE 4, PENNSYLVANIA



Look at all three

A new steam station design approach is bringing higher efficiencies, lower costs, and greater reliability. In this approach, only three basic functions are considered: (1) Steam Generating, (2) Electric Generating, (3) Fluid Handling. Station requirements are first analyzed in terms of the over-all job performed by each of these groups rather than by each individual piece of equipment.

Many of the benefits of this approach occur in the Fluid Handling Group. Here coordination and integration of the wide variety of equipment used can often effect substantial improvement in over-all operation. As steam temperatures and pressures go up, there are increased demands on the fluid handling function. Plant reliability often depends on the effect of one component of the fluid handling group on another during operational transients, either planned or of emergency nature. The solution is coordinated equipment


2. ELECTRIC GENERATING GROUP
TURBINE GENERATOR
3. FLUID HANDLING GROUP
CONDENSER
EJECTOR
CONDENSATE PUMP
CIRCULATING
WATER PUMP

compensated *

WATER LEVEL INDICATORS

Model showing mechanism of Yarway Pressure Compensator. Placed between indicator operating and indicating elements, the compensator mechanism corrects the level indication by changing pointer travel to compensate for variation in water density due to changes in boiler pressure.

(Not shown) Yarway Remote Hi-Lo Alarm Signals (lights and/or horns), operated by the Indicator. May be placed at any location in the plant.

(Not shown) Yarway Electronic Secondary Indicator to provide duplicate reading at any other location. Same size and appearance as primary indicator.

ADVANTAGES OF YARWAY PRESSURE COMPENSATOR

1. Compensating mechanism is applied to the Yarway indicator without change in internal construction of the indicator.

2. Well-known dependability of bourdon tube insures reliability and long life.

3. Trouble-free operation because linkage is simple and direct.

4. For maximum sensitivity, the indicator pointer is mounted on jewel bearings.

5. Rugged shock-resistant mounting carries weight of compensator mechanism without burdening the pointer mechanism.

6. Boiler conditions are readily simulated for check of instrument calibration at operating pressures, with remainder of indicator system under atmospheric pressure.

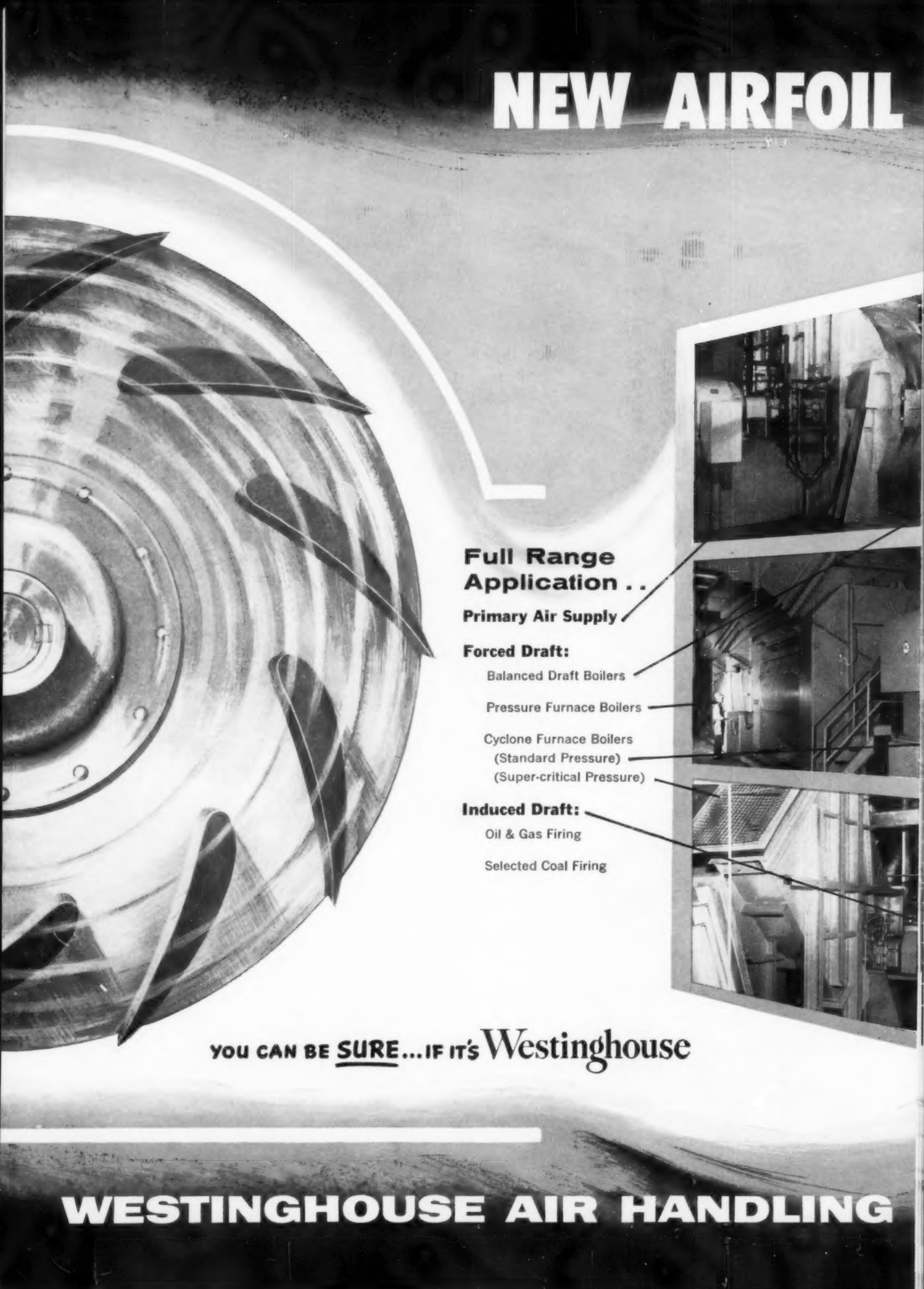
7. Application of pressure-temperature compensation for density changes in boiler water insures desired accuracy of level indication at all operating pressures and at all points on the pointer scale.

**Pressure compensator available on request, at extra cost.*

to specify remote liquid level indicators


WHAT'S SPECIAL ABOUT LJUNGSTROM®
structural details?
. . . many things.
And all make air preheating with a Ljungstrom more economical, less troublesome. The Ljungstrom offers these refinements:
• The welded steel rotor is strong enough to support the heating elements without strain, yet flexible enough to withstand extreme temperature variations.
• An inspection port and strategically located access doors reveal any maintenance needs and make replacement work routine.
• A mass flow soot blower is installed as original equipment at the cold end where deposits are most apt to accumulate.
• The hot end heating surface is made from open hearth steel sheet and the cold end from heavier gauge, low-alloy corrosion-resisting material because corrosion is normally confined to the cold end.
The Air Preheater Corp. is constantly working to improve Ljungstrom heating surfaces, seals, bearings, and other structural details. And, in general, these improvements can be applied to existing units with only minor changes and at nominal cost. Another reason why seven out of ten air preheating installations are Ljungstrom. For the full story on how the Ljungstrom design and construction can cut your fuel costs, increase plant efficiency, write for our 38-page manual.
The Air Preheater Corporation, 60 EAST 42ND STREET, NEW YORK 17, N. Y.

HOW HIGH IS HIGH?


NEW AIRFOIL
Full Range Application . .
Primary Air Supply
Forced Draft:
Balanced Draft Boilers
Pressure Furnace Boilers
Cyclone Furnace Boilers
(Standard Pressure)
(Super-critical Pressure)
Induced Draft:
Oil & Gas Firing
Selected Coal Firing
YOU CAN BE SURE...IF IT'S Westinghouse
WESTINGHOUSE AIR HANDLING

Hall Industrial Water Report

VOLUME 5 | OCTOBER 1957 | NUMBER 5

Waste Is Waste

In some cases, waste water is truly just "waste" and must be disposed of in the least costly manner; in others, waste water may contain valuable materials, so that failure to recover these before discarding the water is "waste" in a different sense.

Specialized knowledge and experience are necessary to search effectively for the economical changes which can be made in a plant to minimize loss of valuable materials, to confine pollution to the smallest volume of waste water, to decide what treating procedures should be used and what control should be exercised. Hall staff engineers and industry specialists have the training and experience required and are ready to tackle your problems.

Who Muddied the Waters

A mid-western tire plant wished to reduce or eliminate pollution of waste water. As a first step, a plant survey was made by Hall Staff Engineer E. G. Paulson.

This survey narrowed the major source of waste water contamination to several plant operations. The next step involved gauging, sampling and analytical work on the plant effluent and on inplant waters. This established that the primary contaminant was suspended solids, presumably from a process where clay slurry was sprayed on an intermediate product. However, material balance calculations disclosed a major discrepancy between estimated clay pollution and actual suspended solids concentration of the waste water.

The third step was a resurvey to definitely identify the suspended solids as clay and to confirm the high concentration in the waste water. The outcome was that the suspended material was almost all clay, that clay was used in only one section of the plant and that the amount of clay getting into the plant effluent was greater than had been estimated.

This case is a good example of how stepwise approach to a pollution problem can pay dividends. Plant engineers and Hall personnel changed the process for applying the clay slurry and another survey showed that the pollution loading was reduced by more than 85 percent. The cost of making the changes will be recovered in 18 months by the saving in process material.

Whittling Away at Waste

More than ten years ago an eastern detinning plant contracted with Hall Laboratories for a long-range program to eliminate objectionable contamination of waste water in the most economical and satisfactory manner.

Initial studies on the sanitary and process water systems were made to determine the pollution load. One of the first results was segregation of the sanitary sewage and its discharge to a municipal sewage system.

The remaining waste water came from seven different locations in the plant.

Continuing study showed three streams to be uncontaminated and one stream to be contaminated only periodically. Investigation was extended to determine whether water could be recycled and whether the volume of polluted water could be decreased.

After inplant changes were made to segregate uncontaminated water from polluted water, there remained three polluted streams, one flowing rinse and two batch dumps. Joint efforts of the plant's research department and Hall Laboratories resulted in development of methods for treating the contaminated waters. An economic study showed that with properly designed treating equipment almost $400 per day could be saved by recovery of valuable materials. This was over and above the operating cost and depreciation on the new equipment.

A more efficient reclamation process eliminated two of the three polluted streams and left one very heavily contaminated batch dump. With only one polluted water stream requiring treatment and with the method of treatment already determined, the problem has been whittled down to a simple answer. This is an excellent example of what can be accomplished by cooperation between plant personnel and Hall engineers.

From Shortage to Abundance

An eastern electrical products manufacturer faced a serious water supply problem. Expanding operations required more water. The two supply sources, plant wells and city water, were inadequate. The wells were already being pumped to the limit of their capacity and the city wanted to supply less water because of increased domestic requirements.

Hall staff engineers were called in to survey the water situation. They found that city water consumption could be reduced 40 percent by reuse and modification of water use in manufacturing processes. They discovered also that because of the long time required to regain maximum pumping capacity after shutting down, the plant operators were running the well pumps continuously, sending much water to waste during non-working shifts.

Two recommendations were made. One involved the changes necessary to reduce city water consumption and the other was to install storage tanks to collect the well water being wasted. The estimated water saving was close to 500,000 gallons per day.

Industrial Water Problems Require Special Handling

There are no "stock answers" to industrial water problems. For information write, wire or call Hall Laboratories, Division of Hagan Chemicals & Controls, Inc., Hagan Building, Pittsburgh 30, Pa.

Water is your industry's most important raw material. Use it wisely.

Hall Laboratories—Consultants on Procurement, Treatment, Use and Disposal of Industrial Water

Turn this page

C·E products for the power field

Utility Boilers

Natural and controlled circulation designs for all requirements of capacity, pressure and temperature.

Nuclear Power Systems

Complete power reactor systems

Reactor vessels, cores, fuel elements, heat exchangers and other components.

Industrial Boilers

Vertical-Unit Boilers (Type VU)

Standard and special designs for capacities from 10,000 to 600,000 lb per hr; pressures to 1400 psi; and temperatures to 1000 F.

Package Boilers (Type VP)

Standardized, shop assembled units in capacities from 4000 to 50,000 lb per hr; pressures to 500 psi; oil or gas firing.

Controlled Circulation Hot Water Boilers (Type HCC)

For large heating and process applications; producing high-temperature, high-pressure water for forced circulation systems.

Special Boilers

Waste Heat — Natural and controlled circulation designs; fire tube designs.

Waste Fuels — Special designs for burning bark and other wood refuse, bagasse, etc.

Marine Boilers

Sectional Header, Bent Tube and Controlled Circulation designs for all capacity, pressure and temperature requirements.

Fuel Burning Equipment

Pulverizers (C-E Raymond Bowl Mills)

Burners — Tangential, Horizontal and Vertical Types for firing pulverized coal, oil or gas, separately or in any combination.

Stokers — Underfeed, Spreader, Traveling Grate and Chain Grate designs.

C·E products for other fields

For Process Plants

Mills, Pulverizers and Air Separators
Flash Drying Systems
Pressure Vessels — columns, towers, tanks; etc.

For Pulp and Paper Mills

Chemical Recovery Units
Flash Drying Systems for lime kiln mud
Bark Burning Boiler Units

For Municipalities

Flash Drying and Incineration Systems for sewage sludge
Refuse Incinerator Stokers
Flash Drying and Calcining Systems for water softening plants

For Railroads

Superheaters and auxiliaries for steam locomotives

For Homes

"Superspun" soil pipe and fittings

COMBUSTION ENGINEERING

C-104

COMBUSTION ENGINEERING BUILDING • 200 MADISON AVENUE • NEW YORK, N.Y.

Landmarks of C

Development of Pulverized Coal Firing

The C-E Pulverized Coal System, pioneer
Oneida Street Station of Wisconsin Electric
Company in 1918, was used in the first powe
tions designed for pulverized coal firing – W
sin's Lakeside Station and Ford Motor Comp
Rouge Station – both built in 1920.

Development of the Water-Cooled Furna

First bottom water screen – Oneida Stree
Lakeside – 1920

First rear wall cooling – Springdale Station,
Penn Power Company – 1923

First side wall cooling – Hell Gate Station,
solidated Edison Company of N. Y. – 1923

First boiler utilizing bottom screen, rear anc
wall cooling – Cahokia Station, Union El
Light & Power Company – 1925

**Development of Today's Most Widely Us
Type of Industrial Boiler**

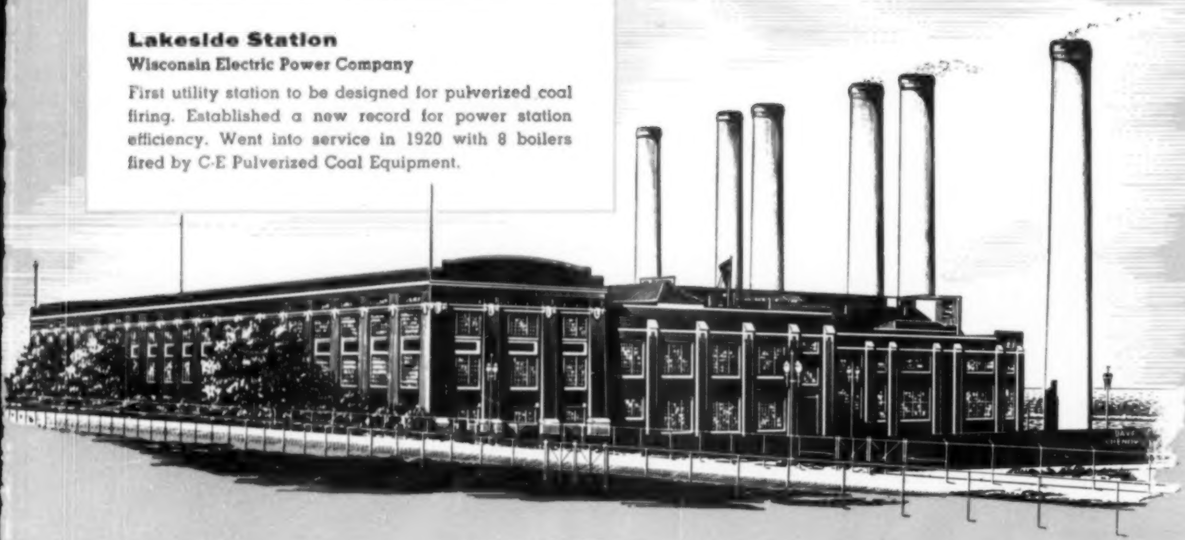
Integrated design of two-drum boiler with
water-cooled furnace. First installation ma
Northampton, Pa. plant of Atlas Portland Ce
Company – 1926

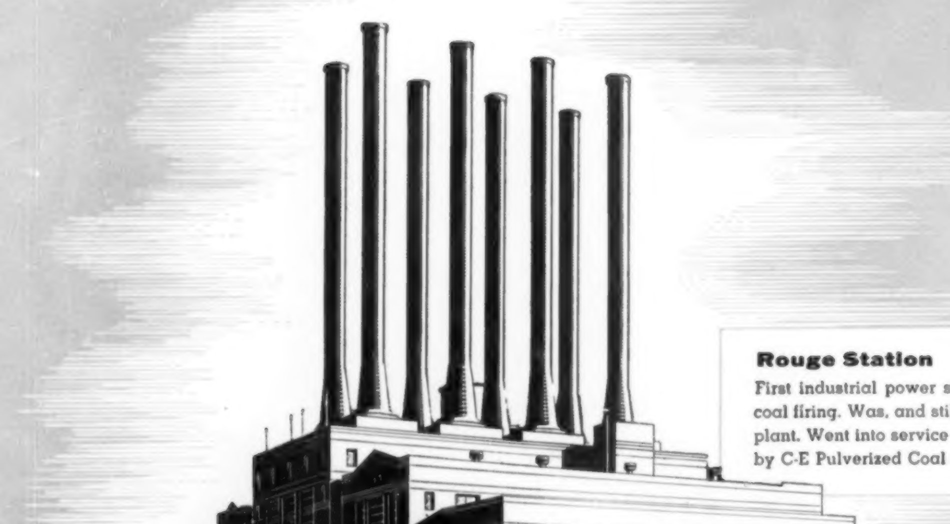
Development of Tangential or Corner Fir

First installation at U.S. Rubber Company, D
– 1927. A further development of tangential
was the vertically adjustable or tilting burne
applied at Buck Station, Duke Power Compa
1940

Lakeside Station
Wisconsin Electric Power Company

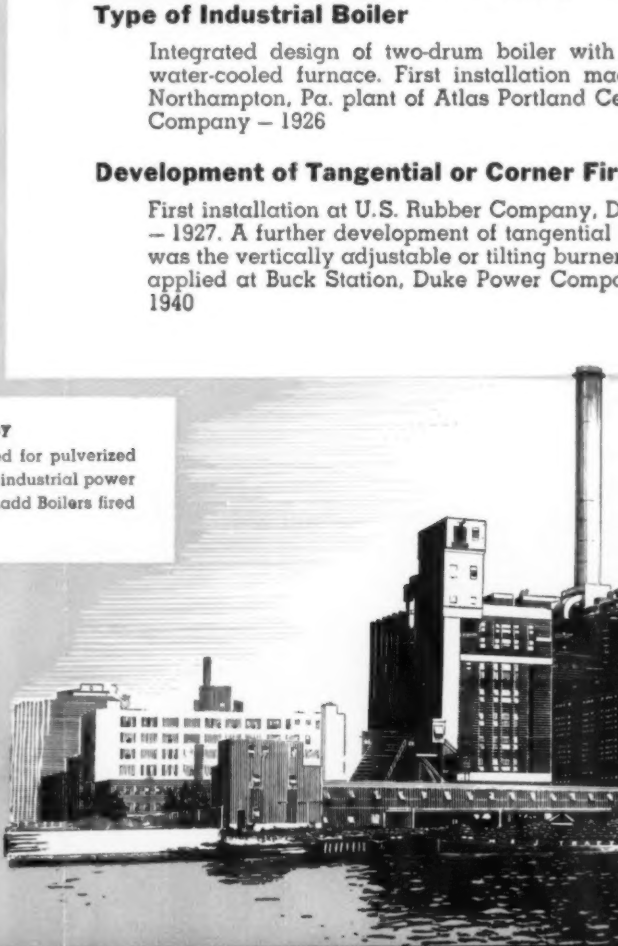
First utility station to be designed for pulverized coal firing. Established a new record for power station efficiency. Went into service in 1920 with 8 boilers fired by C-E Pulverized Coal Equipment.





Rouge Station Ford Motor Company

First industrial power station to be designed for pulverized coal firing. Was, and still is, world's largest industrial power plant. Went into service in 1920 with 8 C-E Ladd Boilers fired by C-E Pulverized Coal Equipment.



C·E power progress

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Pioneering of High Steam Pressures and Temperatures

First 1800-lb pressure boiler – Phillip Carey Company, Lockland, Ohio – 1931

First boiler to use steam temperature above 900 F – Rouge Station, Ford Motor Company – 925 F – 1939

First boiler to use steam temperature above 1000 F – Sewaren Station, Public Service Electric & Gas Company – 1050 F – 1949

First 2350 psi – 1100 F boiler – Kearny Station, Public Service Electric & Gas Company – 1953

First 5000 psi – 1200 F boiler – Eddystone Station, Philadelphia Electric Company – now being installed

Pioneering of High Capacity Boilers

First 500,000 lb-per-hr boiler – Rouge Plant, Ford Motor Company – 1925

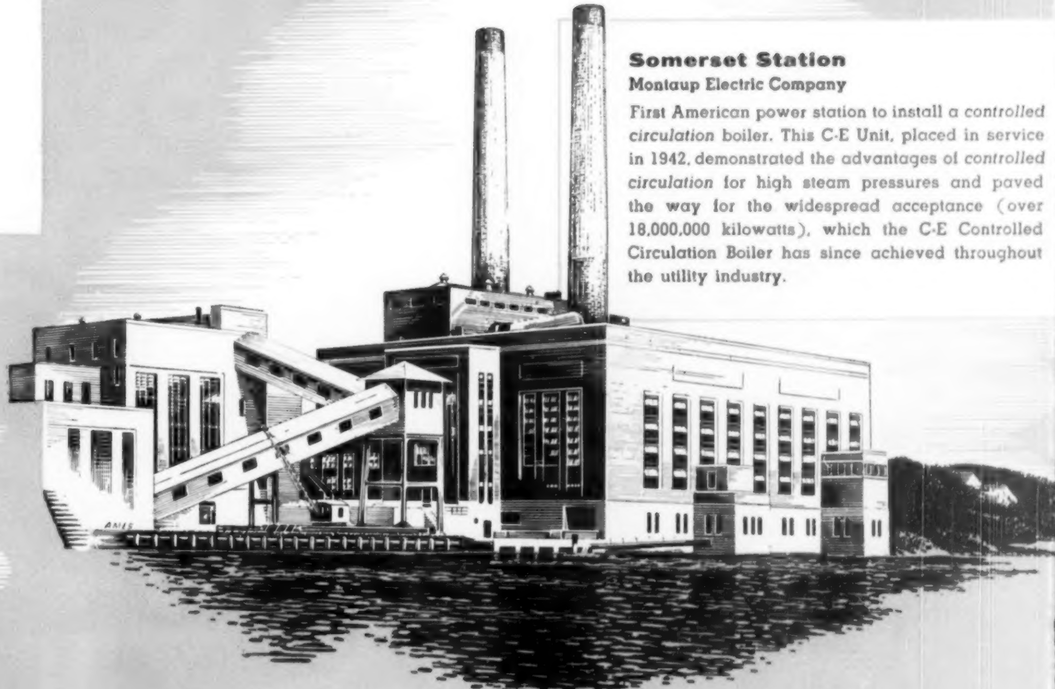
First 1,000,000 lb-per-hr boiler – East River Station, Consolidated Edison Company of N. Y. – 1929

Introduction of Controlled Circulation to American Power Practice

Somerset Station, Montaup Electric Company – 1942. (Since 1950, utilities have purchased C-E Controlled Circulation Boilers for a total capacity of more than 18,000,000 kw – by far the greatest acceptance accorded any basically new design of boiler in the annals of power history.)

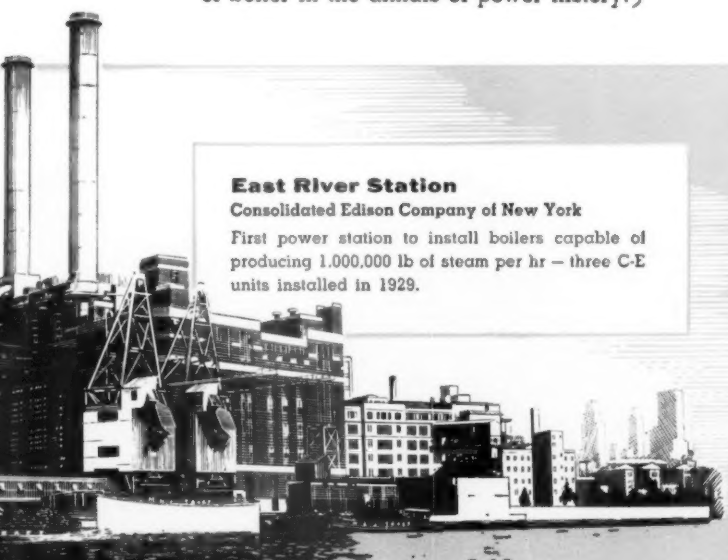
Port Washington Station
Wisconsin Electric Power Company

First utility power station to adopt unit system – one boiler per turbine – for a high capacity installation. Went into service in 1935 with a single C-E Boiler serving an 80,000 kw turbine generator. Set a new record for power station efficiency and held it for 13 years.



Somerset Station
Montaup Electric Company

First American power station to install a *controlled circulation* boiler. This C-E Unit, placed in service in 1942, demonstrated the advantages of *controlled circulation* for high steam pressures and paved the way for the widespread acceptance (over 18,000,000 kilowatts), which the C-E Controlled Circulation Boiler has since achieved throughout the utility industry.



East River Station
Consolidated Edison Company of New York

First power station to install boilers capable of producing 1,000,000 lb of steam per hr – three C-E units installed in 1929.

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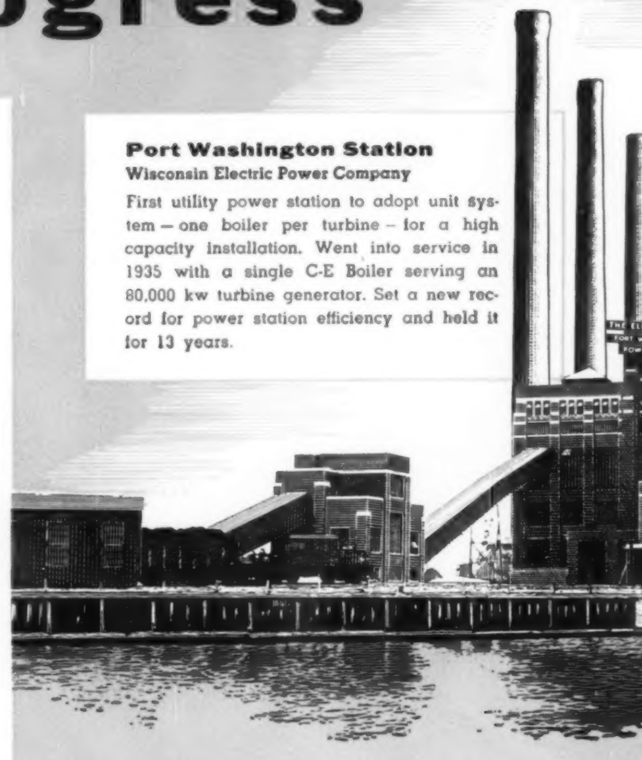

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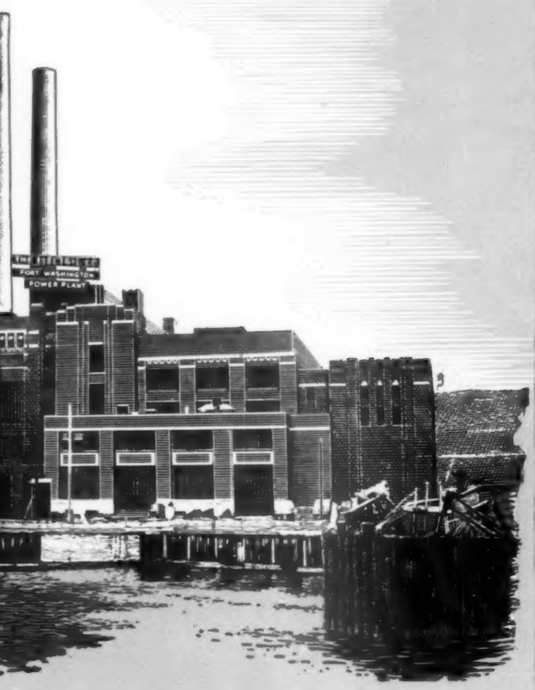

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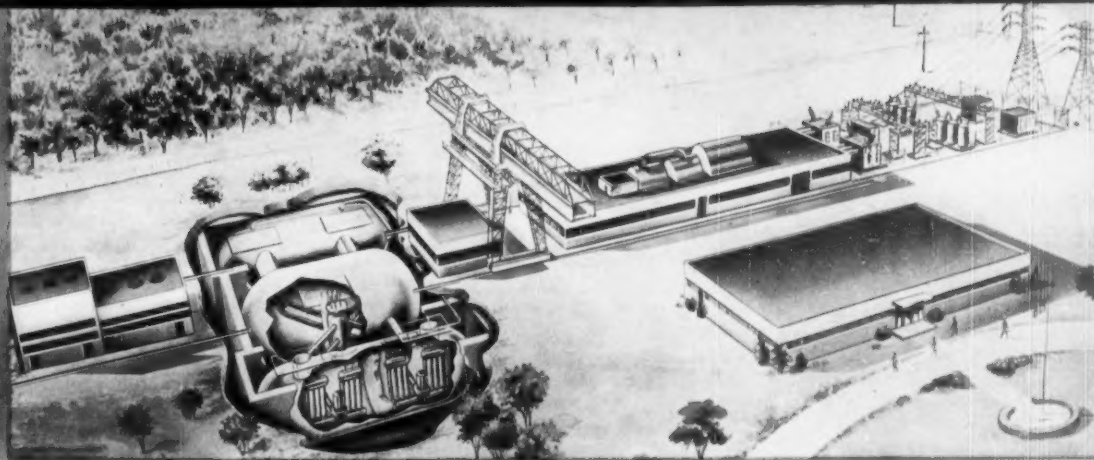
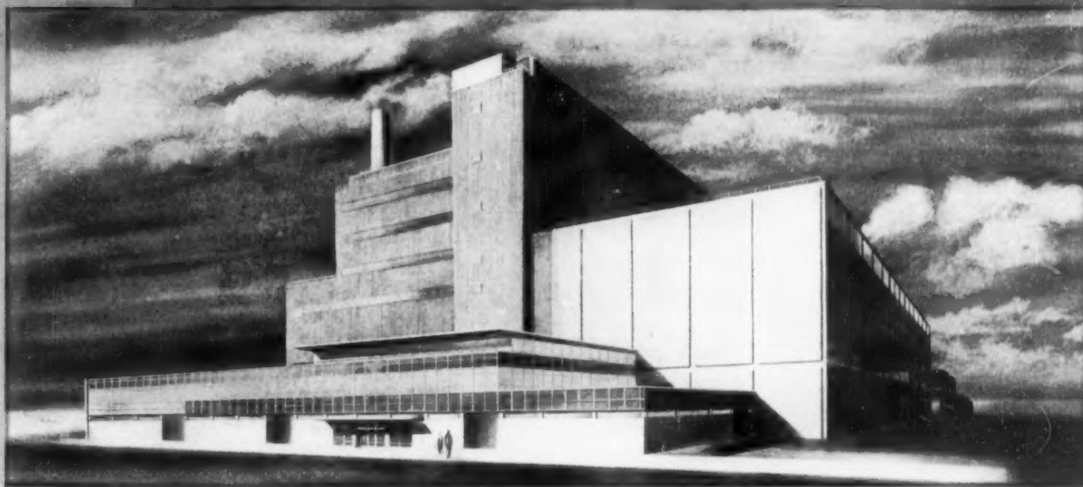
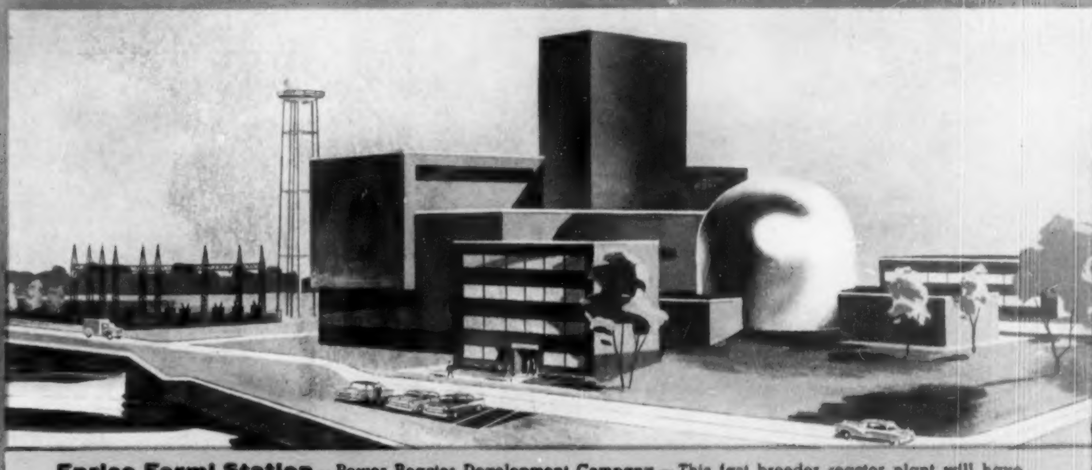


Shippingport Station – **Duquesne Light Company** – The Shippingport Nuclear Power Station, America's first full-scale atomic power plant, is scheduled to go into service the latter part of this year. Designed by Westinghouse Electric Corporation under contract with the Atomic Energy Commission, Shippingport will be operated by the Duquesne Light Company and will have an initial rated capacity of 60,000 kw with an anticipated future capability of 100,000 kw. Combustion designed and built the reactor vessel and internals for this station.



Eddystone Station – **Philadelphia Electric Company** – Now under construction, the initial unit at Eddystone will be a 325,000-kw turbine generator to which steam will be supplied by a C-E Sulzer Monotube Steam Generator at the supercritical pressure of 5000 psi and a temperature of 1200 F with double reheat – the highest steam conditions yet adopted. By virtue of these steam conditions, Eddystone is expected to set a new record for power station efficiency with a heat rate of approximately 8000 BTU per kw-hr. A second C-E Sulzer Unit for this station is on order.



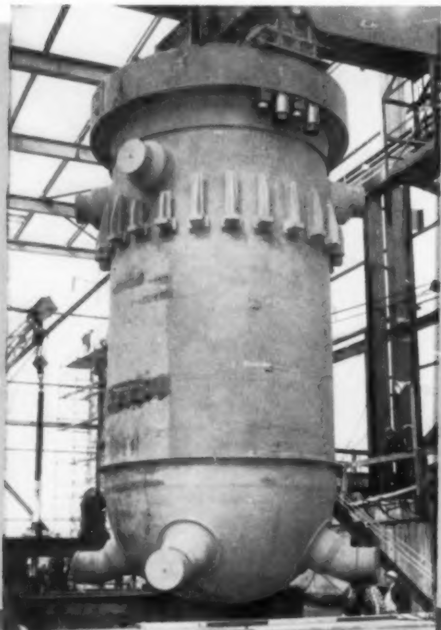
Enrico Fermi Station – **Power Reactor Development Company** – This fast breeder reactor plant will have a capacity of 100,000 kw and will supply electricity to the Detroit Edison System. It is scheduled for completion in 1960. Combustion is building the reactor vessel, internals and rotating plugs for this notable atomic power plant.

a decade of C·E nuclear progress

Combustion's activities in the nuclear field began in 1946 when studies were undertaken to determine the feasibility of power generation from nuclear fuels. Since then the Company has served as consultants and designers for the Atomic Energy Commission, the Navy Department and utility companies on reactor system components. It has designed and manufactured the reactor vessel, shield tanks and rotating plugs for the prototype of the submarine U.S.S. Seawolf and for the Seawolf itself; liquid metal heaters for the U.S. Navy Bureau of Ships and the U.S. Air Force; and the reactor vessel, end closure and internals for the Shippingport Plant, the country's first full-scale nuclear power plant.

Work currently in process includes the fabrication and assembly of five complete reactor cores for the U.S. Navy's nuclear submarine program; the reactor vessel, internals and rotating plugs for the Power Reactor Development Company's Fast Breeder Reactor (Enrico Fermi Station); the reactor vessels and steam generators for Submarine Advanced Reactor as well as reactor vessels, internals and closures for an aircraft carrier and a new type of ship called a frigate. To date, Combustion has done more heavy component work than any other company.

Most significant of the Company's present projects is a contract to design, develop, manufacture and test a nuclear reactor for a new type of submarine, and to serve as prime contractor for the construction of a prototype installation. Combustion was the first company to undertake a naval reactor project using its own facilities.

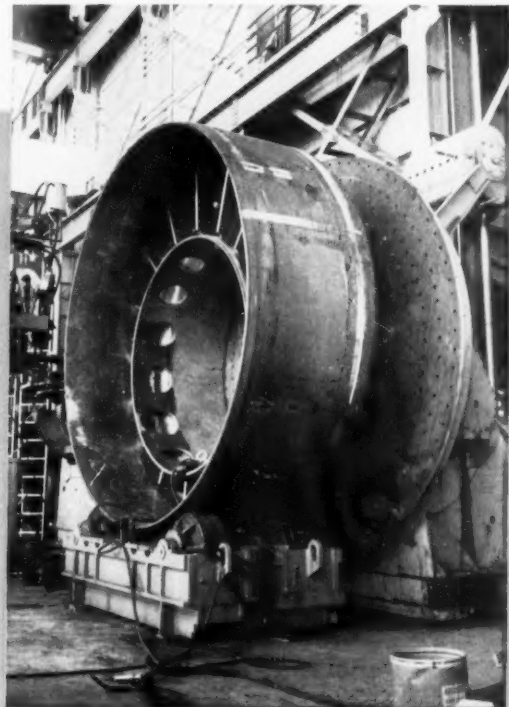


Heaviest unit of nuclear power equipment built to date—235-ton reactor vessel, designed and built by C-E, for country's first full-scale nuclear power plant. View shows vessel being installed at Shippingport Nuclear Power Station, Shippingport, Pa.

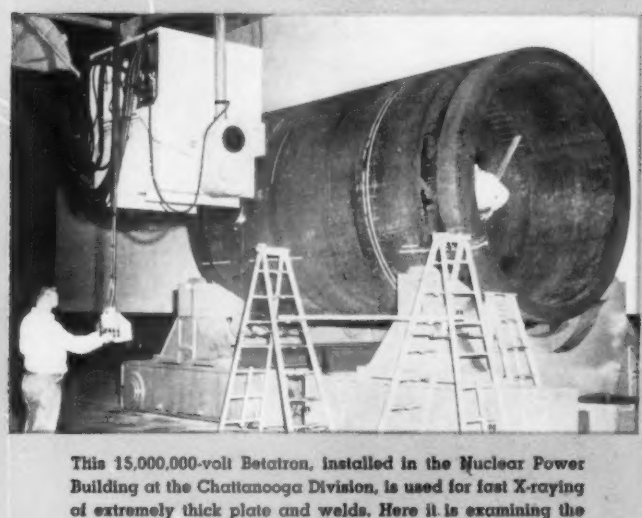
Aerial view of Combustion's Nuclear Power Division at Windsor, Conn., taken earlier this year when construction was nearing completion. This $15,000,000 plant is the largest privately owned facility of its kind constructed thus far. At lower right are the Critical Assembly Buildings. The three buildings in the upper left group are, from top to bottom, the Engineering and Administration Building, the Development Building housing chemical, metallurgical and physical testing laboratories, and the Fuel Element Fabrication Building. In another part of the 530-acre site, the prototype of a nuclear powered submarine is under construction.

Chattanooga Division, largest of Combustion's nine domestic manufacturing plants, is equipped with many special facilities for the manufacture of heavy nuclear components. These facilities are contained in the Nuclear Power Building (upper center), which is 535 ft long by 90 ft wide. Completed last year, this was the first facility in the country to be expressly designed and built for the manufacture of heavy nuclear components.

This IBM Computer System was the first installation of its kind anywhere. Located at C-E headquarters in New York, it is directly connected by transceivers to both Chattanooga and Windsor. Equipped with a "memory" in the form of a battery of magnetic tapes, it can "remember" literally millions of pieces of information and can be used to solve an almost endless variety of engineering problems. For example, it can solve an equation with 18 unknowns in a very few minutes.

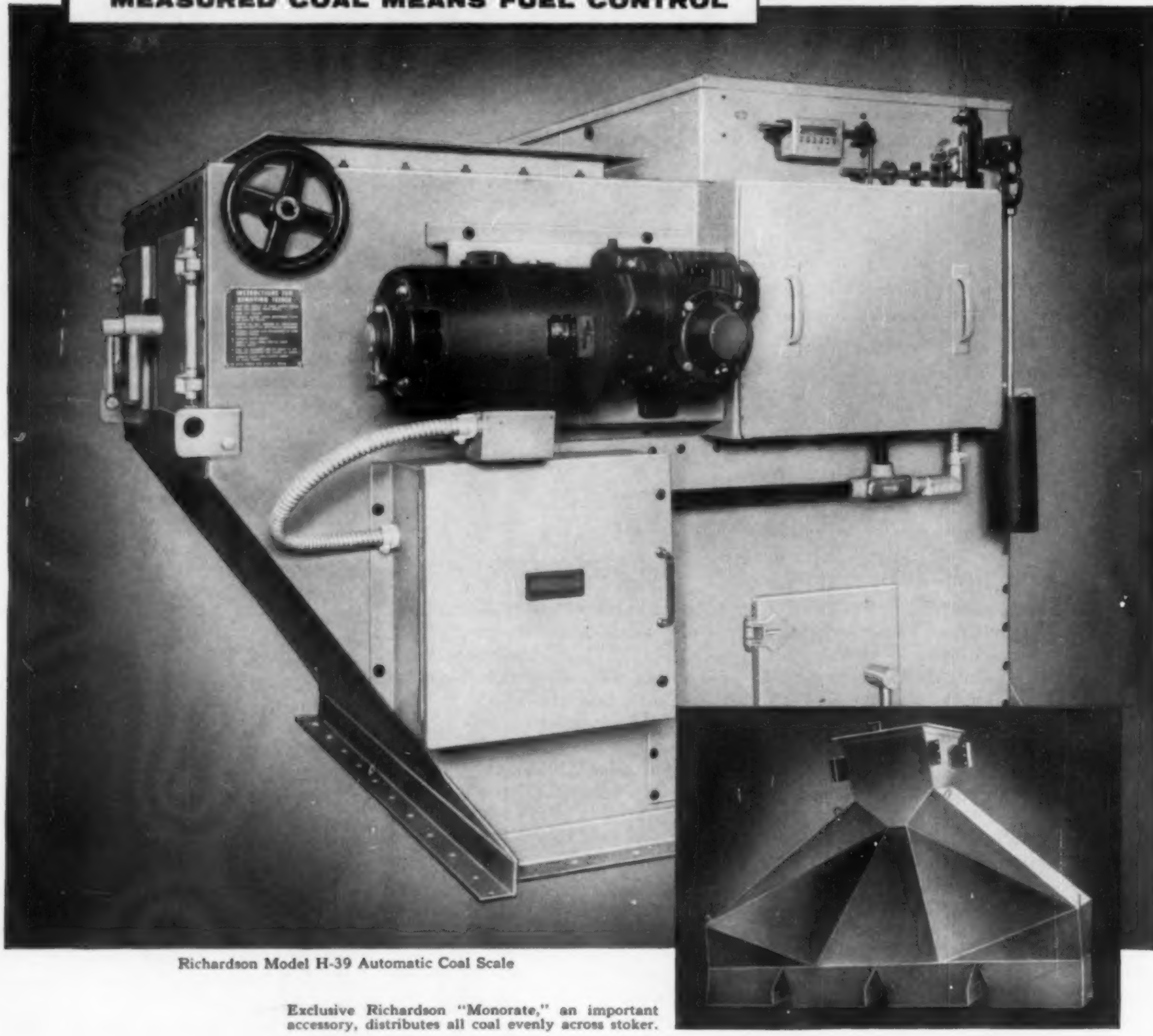


Lower section of reactor vessel for Enrico Fermi Nuclear Power Station being built by Power Reactor Development Company. This highly complex vessel will be constructed of stainless steel throughout. It will be 37 ft high with a diameter of about 14 ft. It is shown here on the 50-ton welding positioner in the Nuclear Power Building at C-E's Chattanooga Division.



This 15,000,000-volt Betatron, installed in the Nuclear Power Building at the Chattanooga Division, is used for fast X-raying of extremely thick plate and welds. Here it is examining the 8½-inch thick wall of a reactor vessel.

MEASURED COAL MEANS FUEL CONTROL



Richardson Model H-39 Automatic Coal Scale

Exclusive Richardson "Monorate," an important accessory, distributes all coal evenly across stoker.

Automatic fuel control with a Richardson H-39

All Richardson H-39 coal scales feature a LARGE 24" x 24" inlet. Coal moves through freely from bunker to stoker or pulverizer, never "arches" in an H-39 feeder or weighing hopper.

Richardson Coal Scales assure top performance, low maintenance, low operating cost, and trouble-free operation under all boiler-room conditions. They provide a continuous, accurate record of fuel consumption.

All contact platework of stainless steel. Quick, easy access to all parts of scale—all positively dust-sealed. All electrical equipment totally enclosed and installed *outside* of dustproof housing—never in contact with coal dust at any time. Endless belts available. Feeder is removable for maintenance. This scale includes *everything* dictated by 40 years of experience in automatic coal weighing.

For stoker fired boilers, the Richardson Monorate Distributor maintains uniform delivery of coarse and fine coal. No internal baffles. Designed for your conditions.

A nation-wide service organization of Richardson specialists guarantees accurate performance of all Richardson installations. Write today for Bulletin No. 0352A and 1349 for complete information.

Richardson

MATERIALS HANDLING BY WEIGHT SINCE 1902

RICHARDSON SCALE COMPANY, CLIFTON, NEW JERSEY

Atlanta • Boston • Buffalo • Chicago • Cincinnati • Detroit • Houston • Memphis • Minneapolis New York • Omaha • Philadelphia • Pittsburgh • San Francisco • Wichita • Montreal Toronto • Havana • Mexico City • San Juan • Geneva, Switzerland • Nottingham, England

THIS IS BAILEY ARMORTUBE CABLE

every foot you install saves you $5 to $6

ARMORTUBE Cable consists of multiple copper or aluminum tubes in a single, flexible armored cable. You string *one* line. You buy *one* set of standard pipe supports or conduit clips. You make a neater, protected installation. Installation costs are reduced tremendously.

Users of copper or aluminum tubing for connecting pneumatic instrument and control lines report that it costs about $2.00 a foot to install single tubes.

It costs the same $2.00 a foot to install Bailey ARMORTUBE Cable.

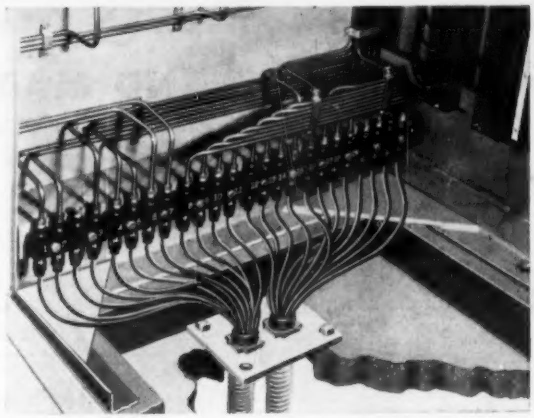
But here's what customers tell us . . .

SAVES $3,000—A chemical plant bought 530 feet of 4-tube Bailey ARMORTUBE Cable and installed it at a saving of $3,000 over the cost of four single tubes.

SAVES $14,000—Another chemical plant bought ARMORTUBE Cable costing $1,345. The saving on installation compared to single tubes amounted to $14,000.

SAVES $60,000—An electric utility bought $14,068 worth of ARMORTUBE Cable . . . saved $60,000 on installation.

Whether your next job consists of 100 or 100,000 feet of tubing, it will surely pay you to check on savings possible with Bailey ARMORTUBE Cable. For more information ask for Product Specification and Price List G91-9.



NOW—to meet increasing demands, this cost-saving product is offered in a full family of sizes and types. In the quarter-inch tube size, ARMORTUBE is available in both copper and aluminum with 2, 3, 4, 5, 7, 8, 10, 12 or 19 tubes. Tubes are protected with galvanized steel armor or a combination of steel armor and thermoplastic . . . with thermoplastic sheath located either over or under the steel. Other sizes are copper tubes in steel armor only: 3/8" in bundles of 1, 2, 3, 4, 7; 1/2" in bundles of 1, 2, 3, 4. G-38

Instruments and controls for power and process

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In Canada—Bailey Meter Company Limited, Montreal

BAILEY METERS


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AND

COMBUSTION

Editorial

Shaping the American City of Tomorrow

American cities as we know them today are caught up in a struggle for their very survival. The automobile which we all accept as part and parcel of our daily lives has, through its gift of mobility, greatly enhanced the suburban way of life. Moreover by putting lower cost real estate within the reach of many the automobile has helped promote a large scale exodus from the city of its important middle class. Then to add further to the big city's woes the automobile by sheer numbers has choked up the city's streets and seriously detracted from the advantages of the central city as a natural hub of activities. There is a very real danger that the modern city's center will suffer blight.

There are many alert to this impending blight and it has been made the subject of discussion by such diverse groups as the President's Advisory Committee on Government Organization, chairmanned by Nelson Rockefeller, and a recent 6-state parley—New York, New Jersey, Pennsylvania, Massachusetts, Connecticut and Rhode Island—involving political officials from governors on down to mayors. This last named parley expressed the belief that the problem went beyond individual cities and encompassed "metropolitan areas." These areas cut across geographic and political lines and hence the solutions as this parley sees it have to come from some cooperative action of Federal, state, county and municipal bodies.

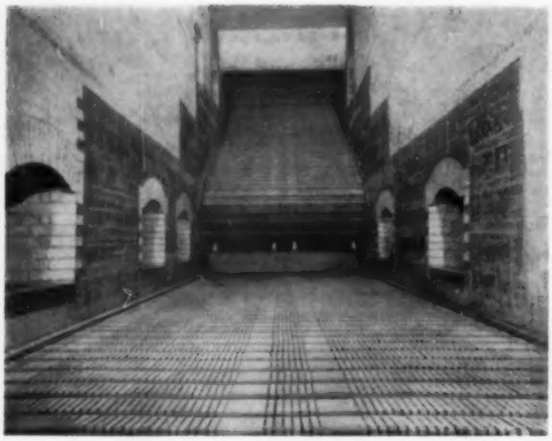
Still another and a refreshingly different view has been expressed by the Greater Fort Worth, Texas, Planning Committee, non-political in origin. They recognize the gravity of the situation and feel that it is of direct concern to government, industry and the individual and accordingly their Committee personnel reflects this spread of interests. They have developed a bold, challenging plan of action to combat their area problem and for a first step they suggest a drastic modernization of downtown Fort Worth. Their premise is "A sick urban area inevitably means a sick suburban area."

The Fort Worth approach we find stimulating and sensible. The typical American city owes its existence and its past development to the fact that it possessed certain natural advantages for the promotion of trade and commerce. In the early formative years of the city the men who operated this trade and commerce very largely shaped the city. We feel the principal reasons for a city's continued vitality is still its trade and commerce. What, then, could be more fitting than to have representation from the ones operating these enterprises on any planning body organized to direct the shaping of the American city of tomorrow.

The public utility industry can draw pride from the fact that J. B. Thomas, president, Texas Electric Service Company, has been prominently identified in the initiation, a year or more ago, of the Greater Fort Worth Plan and has remained an active member of that Plan's Steering Committee.

Certainly the local utility wedded as it is to the area it serves has a heavy stake in the future of that area. Further the usual utility has been most active in recruiting new industries to localities within their territory and has accordingly a double interest in the shape of things to come.

Perhaps out of this search for a solution to the admittedly outdated city center of today we will develop a cultural trade and shopping hub that will serve as the wellspring to the entire area it fosters. And may we hope that the industry supplying the power to make this hub possible will make itself heard early in the planning stages. Now is the time to demonstrate your interests.



Refuse removal is no longer a problem for municipal engineers alone. Today's industrial plants are faced with similar heavy refuse disposal problems. As a result the traditional incinerator is going by the boards to be replaced by designs employing present-day engineering knowledge. This article discusses the reasons behind these new designs and offers simple calculation aids for determining the basic factors.

By H. G. MEISSNER, P.E.

Combustion Engineering, Inc.*

The Engineering of a Modern Incinerator

THE most serious fault with practically all existing incinerators, Fig. 2, is that the refuse is fed intermittently in batches through doors in front or on top of the furnace, onto the fuel bed, so that the latter is either stuffed or starved, with excess air in inverse ratio. Further these units require manual cleaning of the residue, sometimes at quite short intervals, again with much uncontrolled air leakage. Fuel-air ratios, as well as furnace temperatures, are therefore highly variable, reminiscent of the hand-fired coal burning days, now practically extinct. As the refuse falls through the rising gas stream, much of the lighter material is picked up and carried out of the primary chamber unburned. This combustible material is supposed to burn out in the secondary or combustion chamber and settle out as ash in the expansion chamber. Note the clean-out doors in Fig. 2 on the facing page.

The primary furnace in most multi-stage incinerators is much too small. A recent report[1] stated the following: "From the test results it would appear that only a small amount of combustion takes place in the secondary chamber, and that if more combustion space were added to the primary chamber, the secondary chamber could be omitted altogether, or used for an entirely different purpose . . ." such as spray chamber for cooling and cleaning the gas, etc.

For example, a common value for the combined furnace and combustion chamber volume has been 25 cu ft per ton of rated capacity, which works out at a very conservative 16,700 Btu per cu ft per hr when using 417,000 Btu's per hr (see Calculations Section, p. 40), the value for heat released in burning refuse at the rate of a ton per day. However, only 10 cu ft of this is allocated to the primary furnace, so that the heat release in this furnace actually is (417,000/10) or 41,700 Btu per cu ft per hr, which is more than double the recommended rate (20,000 Btu per cu ft per hr).

A second fault with practically all such multi-stage furnaces is the lack of secondary or overfire air to help in completing the combustion of the fixed carbon on the grate, as well as the unburned gas which leaves the primary furnace. Experience with other solid fuels has shown that such overfire air is essential, both to provide required oxygen, and to mix the escaping gas and air, so that combustion may be completed. To be effective such overfire air must be introduced through properly designed and located nozzles, with sufficient velocity to assure adequate penetration and turbulence, for which a fan is required. The natural draft openings which are sometimes provided are completely ineffective as regards both penetration and turbulence, and serve only to further cool an already cold furnace, and so retard combustion thereby creating more air pollution problems.

Claims have been made that the combustion and expansion chambers act as settling places for the fly ash, and they may be provided with quite elaborate baffles to assist in throwing the solid particles from the gas stream. Such claims are refuted by test reports, which show that average collection efficiency is in the 10 to 15 per cent range, whereas at least 50 per cent may be required to meet existing air pollution ordinances. Unless continually removed, fly ash which is deposited in the settling chambers is almost sure to be re-entrained and carried on out of the stack as the gas velocity increases.

Fig. 1—Large municipal incinerator (250 tons in 24 hr capacity) employs an inclined or drying grate before refuse reaches horizontal burning area

* Design Engineer, Industrial Division

[1] University of California, "Sanitary Engineering Project" Bulletin No. 6, Nov. 1951.

Present-Day Conception

The modern design, which incorporates traveling grate stokers as shown in Figs. 1 and 3 takes full advantage of the experience gained in the burning of other solid fuels, with hopper feed of the refuse to the grate, so that the fuel bed is uniform and continuous, with little or no air leakage. Burning rate is controlled by the grate speed, rather than by the opening and closing of charging gates, so that the work of the charging floor operators is confined to keeping the hoppers full.

The moving grate discharges the residue of cans, bottles, ash and miscellaneous non-combustibles, as fast as it accumulates, so that the fuel bed is always clean and active. Higher average burning rates can therefore be maintained, without excessive fly ash carryover, or furnace maintenance, as there is no need to speed up after a slowdown for cleaning, as with batch feeding.

Furnace temperature can be held close to the desired point, either manually or automatically, because of the steady flow of refuse to the furnace, and the lack of air leakage through open charging gates or ash pit doors. This not only assures improved combustion, with a minimum of odor and fly ash, but also reduces furnace maintenance and outage, by elimination of the temperature shock, which is the greatest cause of spalling of brickwork and failure of arches. Spare units are no longer required, with a consequent reduction in cost of equipment and building space.

As the moving grate carries the refuse from the base of the hopper over the air zones, the fuel is first dried and ignited, then the volatile combustible is driven off, and finally the fixed carbon is consumed. This progressive combustion permits close control of the air requirements at all stages of combustion, as the separate zones under the grate are adjusted to supply the air where needed.

As illustrated in Figs. 1 and 3, the combustion volume determined in above example is concentrated in one large furnace, where adequate turbulence and mixing are obtained by use of overfire air jets. The temperature in this furnace is maintained high enough, in the 1600- to 2000-deg F range, to completely burn out all combustible matter, with no odor remaining, and the gas velocity is low enough to minimize the fly ash carried out.

Advantages of Modern Design

The application of the traveling grate stoker to refuse incineration has greatly increased the unit size and capacity, which has been limited in the past by the use of manually handled scrapers, slice bars and other cleaning tools. The trend is therefore, towards fewer and larger incinerators, at materially reduced cost and operating labor.

The increasing use of air-cooled, suspended-refractory furnaces, with non-slagging carborundum blocks where needed, or water cooled furnaces, when practical, has helped greatly in promoting these larger, more reliable units, the availability factor for which is practically 100 per cent with time out for unscheduled repairs almost unknown.

Replacement of the large and costly combustion, settling and expansion chambers and 200-ft stacks with dust collectors or scrubbers as noted below, greatly reduces the building area and first cost, with the added assurance that increasingly strict air pollution ordinances will be easily satisfied.

Mechanization of both refuse and residue handling can now be carried as far as desirable, depending on plant size, location, labor conditions or similar factors.

Automatic control and instrumentation are also practical, and usually profitable, as maintenance of uniform furnace draft and temperature, burning rate and combustion air, can all be done automatically, leaving the operators free for other duties.

The net result of these improvements in incinerator design and operation is a material reduction in first cost, maintenance and labor, with a desirable increase in cleanliness, odor and fly ash elimination.

Disposal of the combustion products is an important consideration which may be solved in one of several ways, depending on local factors.

Removal of Combustion Products

Straight incineration to reduce the refuse for cheaper disposal presents the problems of hot gas and fly ash. The usual arrangement as noted above has been to pass the gas through a series of expansion chambers, with or without baffles, where the fly ash was supposed to settle out for subsequent removal. The so-called cleaned gas then passed directly to a refractory lined stack, built high enough to avoid excessive neighbourhood nuisance.

Power plants burning solid fuel, long ago gave up this crude layout in favor of wet or dry dust collectors because of their much higher collection efficiency. For the dry type dust collectors, generally of the multi-cyclone

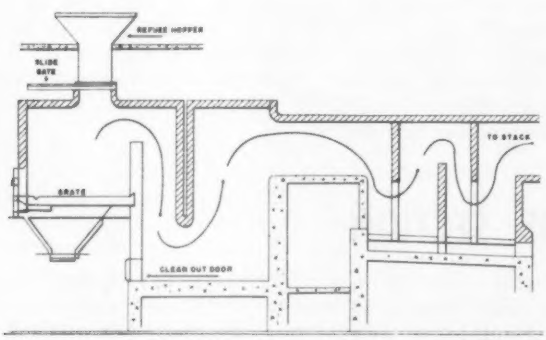


Fig. 2—Existing incinerators feed refuse intermittently upsetting fuel-air ratios, furnace temperatures and causing variable fly ash discharge

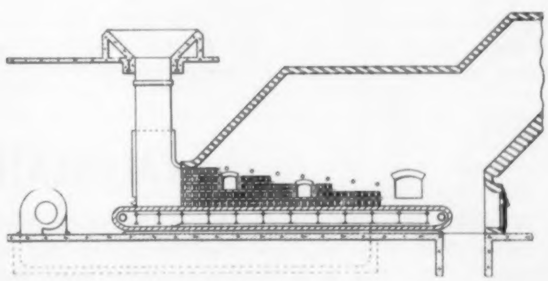
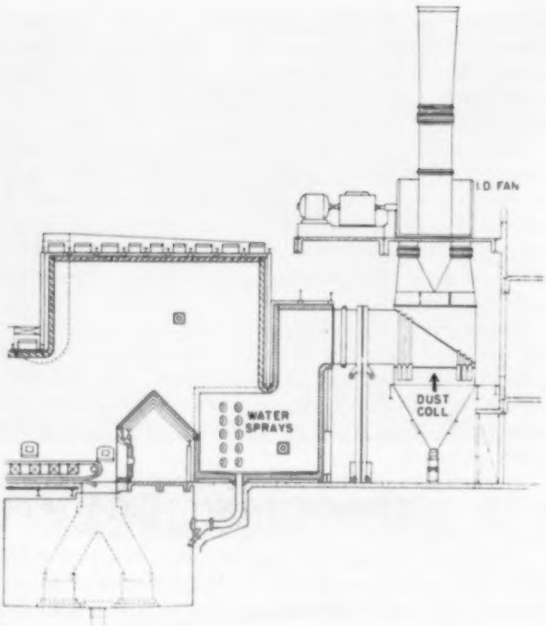


Fig. 3—Modern incinerator incorporates traveling grate stokers with hopper feed to give uniform fuel bed and even furnace temperatures



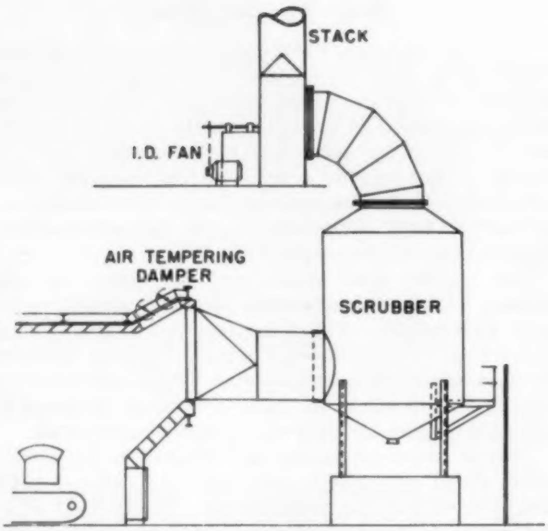


Fig. 5—Wet type of dust collector connects to the combustion chamber of a modern incinerator design such as Fig. 3 in the above fashion

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Fig. 4—The application of dust collectors such as the dry one, left, with 85 per cent or so collection efficiency permits lower stack heights

design, the gas is first cooled to about 700 F by tempering with cold air or by use of water sprays or a combination of both. The cleaned gas then retains enough heat to superheat this moisture and to aid in producing stack draft, with an induced draft fan to overcome the dust collector resistance and provide the required gas velocity for efficient operation. The dry dust may then be carried to a silo or storage tank by pneumatic or similar conveying equipment. Fig. 4 shows a typical example of a dry dust collector installation, which is 85 per cent or more efficient in fly ash removal.

The water required for our 100 T unit is determined from Fig. 10, Calculations Section as 36 gpm. Equivalent tempering air requirement is 36,000 cfm. When water from a pond, river or other source is available, the wet washer or scrubber may prove equally satisfactory. The waste gas is first sprayed down to about 200 F on entering the scrubber, and the dust is then washed out by passage over a series of wetted baffles. The partly dried gas is then discharged through a suitable I.D. fan to the stack at under 200 F. See Fig. 5 for typical layout. The efficiency of such a scrubber is in the high 90 per cent range. The wet fly ash is flushed into a tank or pit for settling and removal by grab bucket to trucks, or for direct discharge to swamp land or fill area. Water requirement for this scrubber is 85 gpm for our 100 T unit or about 2 gpm per million Btu per hr. Much of this water may be recirculated. Simple forms of spray chambers may be satisfactory in many cases, depending on refuse, location of plant or similar factors.

Waste Heat Boilers

When the incinerator location is suitable, the hot gas may be passed through a boiler or hot water heater, for the generation of power or for heating purposes before going to the dust collector. Most incinerators are in operation not more than five days per week, as collections are seldom made over the weekend, and storage facilities for this extended period are generally impractical. For any use of steam or power requiring continuous output, auxiliary fuel such as oil or gas would be required.

The waste gas may also be used in flash drying of sewage sludge, in which case the incinerator and sewage treatment plants should be built adjacent to one another.

Gas Turbines

Gas turbines have interesting possibilities as the gas may be passed over air heaters, the hot air being compressed and utilized for turbine operation.

Air heaters for combustion air are not generally desirable with refractory furnaces, as the preheated air increases materially the furnace temperature so that slagging and maintenance troubles may be aggravated. For water-cooled furnaces, especially in connection with waste heat boilers, or for gas turbines, such use of air heaters may be justified.

CALCULATIONS SECTION

While highly variable in appearance, the typical refuse is quite uniform in chemical analysis, fitting into the "Family Tree," Fig. 6, of its close relations, wood, bark and bagasse, all of which have been burned successfully for many years. Considering that paper, cartons and crates are wood or wood products, this chemical relationship is easily understood, and it can be used to our advantage, as the efficient combustion of these cellulose fuels has been greatly accelerated during the past few years and its problems fairly well understood.

REFUSE INCINERATORS

Comparison of Conventional Empirical Design vs. Modern Scientific Design

Highly variable appearance of refuse has been claimed to make incinerator design most difficult engineering feat, entirely different from that for other solid fuels.	Variables in refuse found to comprise mostly non-combustible residue, moisture, sizing and appearance, as chemical composition is quite uniform. Design no more difficult than for other fuels such as wood and bagasse.
Selection of equipment and furnaces is based on tons per day or lb per hr regardless of heat content of refuse which is affected by moisture, ash and other factors. Parameters and complicated logarithmic formulas are used by designers, with no common denominator, so that comparison of designs or performance is impossible.	Selection is based on heat generated in furnace, in million Btu per hr which is real measure of grate and furnace sizes, as well as air requirements. Gas and air are measured in lb per million Btu, from which the total lb per hr are easily determined. Combustion rates can thus be shown as Btu per sq ft of grate or per cu ft of furnace volume for comparison.
Intermittent batch feed thru furnace roof or front causes fuel bed to be alternately stuffed and starved, so that it is impossible to regulate fuel-air ratio for efficient combustion.	Hopper feed permits continuous and uniform supply of refuse, with minimum air leakage easily regulated fuel-air ratio. Burning rate controlled by grate speed.
Intermittent manual removal of residue thru open ash pit doors at short intervals causes fuel bed disruption and inrush of cold air, which is especially troublesome when residue content is high. Constant manual attention is required for both fuel feed and residue removal.	Continuous discharge of residue to sealed ash pit keeps fuel bed clean and active and avoids cold air inrush. Grate speed is adjusted to suit residue content as well as feed rate, with no manual cleaning. Full automatic control is practical. Labor requirement both on charging and incinerator floors materially reduced.
Variable furnace temperature caused by batch feeding and inrush of cold air thru open chutes results in poor combustion, and high furnace maintenance, because of heat shock and spalling of brickwork.	Uniform furnace temperature can be automatically maintained, because of continuous fuel feed and sealed hopper design, thus assuring complete combustion, with minimum refractory maintenance.
Pile burning prevents proper regulation of air thru grate as fuel bed contour is constantly changing. Excess air enters thru thin spots, with deficiency in center of pile.	Progressive combustion on traveling grate surface permits correct supply of air to fuel bed, as the undergrate air zones can be adjusted to reduce excess air where not desired, as at discharge end of grate.
Primary furnace volume is generally much too small for completion of combustion. Multiple expansion and settling chambers with baffles and mixing arches have been shown in tests to be very inefficient as well as costly. Practically no combustion takes place beyond primary furnace, and fly ash collection efficiency may be as low as 10 to 15 per cent.	Required combustion volume is concentrated in large primary furnace, where fuel is completely burned, with overfire air to promote mixing. Furnace gas velocity is low to reduce fly ash carryover, and high efficiency (85 to to 95 per cent) dust collectors or scrubbers are used to clean gas stream. Space required is reduced by 25 to 33 per cent because of elimination of combustion and settling chambers with corresponding reduction in building costs.

A large Western university[2] reports as follows on the fuel value of municipal refuse: "Analysis made of samples of the refuse burned during the tests showed that the heat of combustion on a moisture and ash-free basis was very close to that of cellulose (8000 Btu per lb) regardless of the chemical composition of the fuel. This fact simplified the calculations on the heat process, and made it possible to predict the behavior of the material when it was burned. The heating value of the refuse was between 7000 and 8000 Btu per lb on a dry ash-free basis. The most important variable was the moisture in the refuse, which is considered as the burden, or the energy-consuming load on the incinerator."

The main constituents of municipal refuse show moisture and ash-free heating values as follows: Wood, 8420; Brush, 8600; Paper, 7900; Garbage, 7280; Average, 8050. With this knowledge as a starting point we can consider municipal refuse and for all practical purposes industrial refuse as just another solid fuel, to be burned as completely as possible, with a minimum of first cost, operating labor and maintenance—rather than as something unknown and mysterious, which is no longer the case. The only precaution is that industrial and other types of refuse should be checked for heating value before use since they may vary from the above average either higher or lower.

Among solid fuels related to a typical refuse, in addition to wood and bagasse, are peat, lignite, bituminous coal and anthracite, all derivatives of wood or similar cellulose matter, a few million years older, as shown in Fig. 6. We can therefore apply our latest combustion designs and practices that have made our industrial furnaces so much more efficient and economical than their predecessors.

To accomplish this we first convert the refuse into heat produced in the furnace. The heat unit generally used

[2] University of California, "Sanitary Engineering Project," Bulletin No. 6, Nov. 1951.

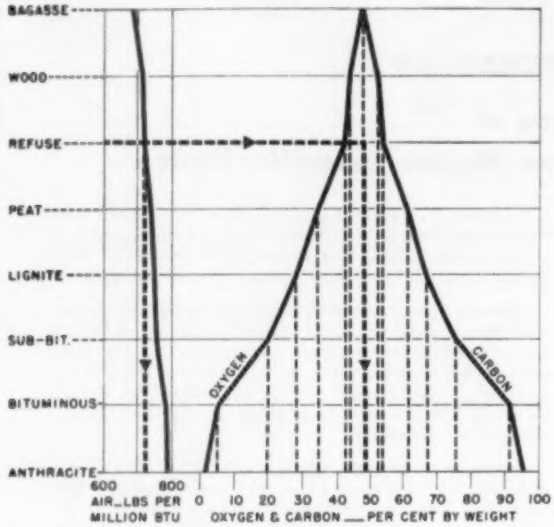


Fig. 6—Refuse fits into a "family tree" of combustible material in the relationship to wood and peat as shown above

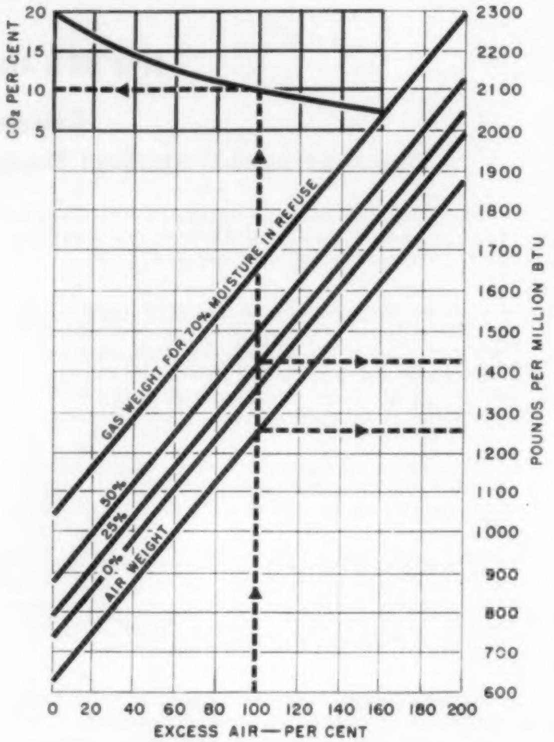


Fig. 7—Air and gas weights for refuse with different moisture contents can be determined quickly from this chart →

is the Million (1,000,000) Btu per hr, which is the product of the fuel burned in lb per hr times the heating value in Btu per lb as fired. In the following example we have assumed a refuse having a moisture and ash-free heating value of 8,000 Btu per lb, with 25 per cent moisture and 12.5 per cent ash (inert material). The as-fired heating value is therefore $8000 \times [1 - (0.25 + 0.125)]$ which equals 5,000 Btu per lb.

Air and Gas Weight Determination

The above University of California bulletin stated that the theoretical air required for complete combustion of the 8000 Btu refuse fuel was 5 lb of air per lb of combustible. For 100 per cent excess air, the lb of air per million Btu then becomes $\frac{1,000,000}{8000} \times (5 + 5) = 1250$.

For 25 per cent moisture content, which corresponds to 0.33 lb of water per lb of dry combustible, the lb of gas per million Btu is then $\frac{1,000,000}{8000} \times (5 + 5 + 1 + 0.33) = 1426$.

Air and gas weights are measured in pounds per million Btu as shown in Fig. 7. For 100 per cent excess air, which is required to hold the furnace temperature at or below 2000 F, the air weight per million Btu is 1250 lb, and for the above 25 per cent moisture in the refuse, the corresponding gas weight is 1426 lb per million Btu. The following example shows how these values are used.

Rated capacity, tons per day (24 hr. or as specified)	100 tons
Pounds per hr for 24-hr operation	8340 lb
Million Btu per hr—8340 × 5000	41.7 MBtu
Grate area at 300,000 Btu per sq ft per hr heat release (41.7/300,000)	139 sq ft
Furnace volume at 20,000 Btu per cu ft per hr (41.7/20,000)	2,085 cu ft
Furnace height required (300,000/20,000)	15 ft
Total air weight at 100% excess air (41.7 × 1250)-lb per hr	52,400 lb/hr
Air volume including furnace leakage (at 100 F)	12,300 cfm
Air supplied by forced draft and overfire fans, at 85% of above	10,450 cfm
Gas weight leaving furnace (41.7 × 1425)	59,400 lb/hr
Gas volume corresponding to above weight at 2000 F	60,300 cfm

Gas Velocities

From this gas quantity we can determine the velocities in the furnace as well as required flue area for any desired gas velocity, together with chimney size and other data.

Vertical gas velocity above fuel bed (60,300/139)	435 ft/min
Horizontal gas velocity at furnace outlet for 8-ft width of furnace (60,300/8 × 15)	500 ft/min
Cross-sectional area in chimney or flue at 1000 ft per min gas velocity (60,300/1000)	60.3 sq ft

These values are easily converted to the weight basis, such as per ton of rated capacity, or similar units, for comparison. We start by moving the decimal point in the above example, two places over.

TABLE I—TABULATION FOR INCINERATOR SELECTION

Tons per day (24 hr)	50	100	150	200	250	300
Lb per hr	4,160	8,340	12,500	16,600	20,800	25,000
Million Btu per hr	20.8	41.7	62.5	83.4	104.0	125.0
Grate area—sq ft	69.3	139.6	208	277	347	417
Furnace volume-cu ft	1,040	2,080	3,125	4,160	5,200	6,250
Forced Draft—cfm	5,860	10,200	15,200	20,400	25,150	30,325
Gas weight at furnace outlet—lb per hr	29,650	59,400	89,000	118,500	148,000	178,000
Gas volume at 2000 F—cfm	30,150	60,300	91,000	120,600	150,200	180,900
Flue area at 1000 fpm—sq ft	30.7	60.3	91.0	120.6	150.2	180.9

One ton per day equals 83.4 lb per hr, equivalent to 417,000 Btu per hr.

The combustion air becomes 524 lb per hr per ton of rated capacity. The gas weight at 100 per cent excess air is 594 lb per hr per ton. Equivalent weight at 50 per cent excess air is 467 lb per hr per ton or 1110 lb per million Btu per hr.

The combustion rate in lb per sq ft per hr is (300,000/5000) equals 60 lb.

The furnace volume becomes (417,000/20,000) which equals 21 cu ft per ton.

Allowable Dust Loading

The dust loading limitation set by the ASME model code of 0.85 lb of fly ash per 1000 lb of gas at 50 per cent excess air, converts to $0.85 \times (1110/1000)$ which equals 0.943 lb per million Btu.

Fan Sizes

Fan sizes are obtained by taking the above air and gas volumes, together with static pressures based on test data, and adding the standard fan tolerances, in accordance with established power plant practice.

It will be noted that variations in the unit heat value, which affect all other results, are taken care of in the third item above. For an as-fired 4000 Btu refuse, having for instance 50 per cent moisture plus ash content, the total heat input becomes 33.4 million Btu per hr. For industrial refuse, which may average 6000 Btu per lb as fired, this heat input becomes 50.0 million Btu per hr. The design should therefore be based on the highest average unit heat value that may be expected, and the resultant million Btu total is that used in subsequent calculations.

It is apparent that the selection of equipment and sizing of furnaces, flues, dust collectors, fans and stacks on the above basis, is both simpler and sounder than the former empirical, hit-or-miss selections that had no common denominators, or those based on complicated parameters and logarithmic functions. Comparison of several installations can now be made on the basis of Btu per sq ft of grate, or per cu ft of furnace volume, and fly ash emission or dust loading is easily related to the million Btu per hr fired, or to unit gas weights. See typical tabulation Table I for incinerator selection.

Furnace temperature, tempering air or water spray requirements for gas cooling, and similar data are also readily determined on this million Btu basis. Note Fig. 8 which shows the furnace temperature obtained with various excess air and moisture contents, and Fig. 9 which gives the water and air requirements for tempering the gas.

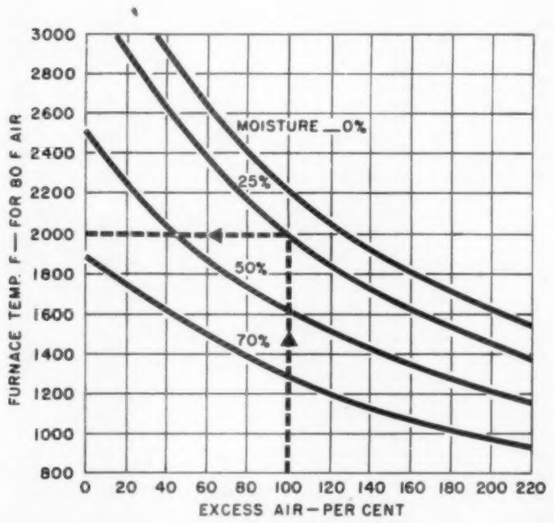


Fig. 8—The furnace temperature to be expected under actual working conditions reflects the influence of moisture content and excess air flow

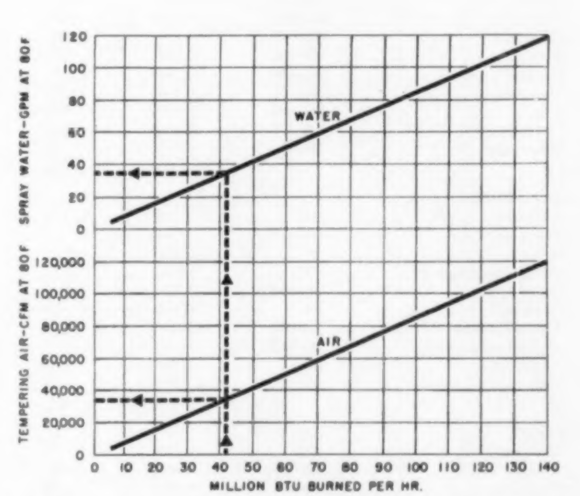


Fig. 9—Tempering air flow or water spray requirements to cool furnace gases to the level required for optimum collector performance can be selected with this graph

World Power Data—1956

A Report Issued by the Bureau of Power, Federal Power Commission, June 1957

The following data show the installed electric generating capacity at the end of 1956 and annual electric energy production for the year 1956, hydro, thermal and total, for all countries of the World. The type of electric current available, population and kilowatt-hours per capita are also given for each country.

This information is from published material received by the Federal Power Commission from many sources and from despatches of United States consular agents throughout the world. Some approximations and estimates are included, in most cases to bring reported data for former years up-to-date for 1956. A few revisions of previously reported populations and capacities are included.

The capacity and production shown include both utility and industrial. Total United States industrial capacity and production included are 16,561 megawatts and 83,302 million kilowatt-hours, respectively.

WORLD POWER DATA—1956
TOTAL INSTALLED ELECTRIC GENERATING CAPACITY AND ANNUAL ELECTRIC ENERGY PRODUCTION, INCLUDING INDUSTRIAL

Geographical Divisions	Type of Current, Cycles	Population (1000)	Installed Capacity 1000 Kw			Energy Production Million Kwhr			Kwhr per Capita
			Hydro	Thermal	Total	Hydro	Thermal	Total	
NORTH AMERICA									
Alaska	60	210	58	80	138	150	200	350	1667
Canada	60—25	16,081	13,450	1,830	15,280	83,250	5,500	88,750	5519
Mexico	60—50	30,538	1,000	1,020	2,020	3,870	3,954	7,824	256
United States	60—25	168,091	26,299	110,697	136,996	125,223	558,671	683,894	4069
		214,920	40,807	113,627	154,434	212,493	568,325	780,818	3633
CENTRAL AMERICA									
Canal Zone	25	55	46	31	77	257	...	257	4673
Costa Rica	60	988	54	27	81	241	30	271	274
El Salvador	60	2,268	43	29	72	105	95	200	88
Guatemala	60—50	3,350	26	18	44	80	29	109	33
Honduras[1]	60	1,711	3	17	20	10	60	70	41
Nicaragua	60	1,300	8	25	33	25	86	111	86
Panama	60—50	934	...	40	40	...	160	160	172
		10,606	180	187	367	718	460	1,178	111
SOUTH AMERICA									
Argentina	50	19,470	100	2,100	2,200	450	5,900	6,350	327
Bolivia	50—60	3,235	90	40	130	175	275	450	139
Brazil	50—60	59,846	2,848	667	3,515	13,500	2,250	15,750	263
Chile	50—60	6,941	526	634	1,160	2,250	1,830	4,080	588
Colombia	60—50	12,939	284	260	544	1,250	600	1,850	143
Ecuador	60—50	3,777	26	40	66	80	170	250	66
Guiana[2]	50—60	750	...	55	55	...	125	125	167
Paraguay	50	1,601	...	47	47	...	85	85	53
Peru	60—50	9,651	266	172	438	900	600	1,500	155
Uruguay	50	2,650	128	184	312	700	500	1,200	452
Venezuela	50-60	5,949	75	430	505	250	1,105	1,355	228
		126,809	4,343	4,629	8,972	19,555	13,440	32,995	260
WEST INDIES									
Bahamas	60	85	...	15	15	...	45	45	530
Bermuda	60	40	...	20	20	...	60	60	1500
Cuba	60	6,000	7	632	639	20	1,980	2,000	333
Dominican Republic	60	2,608	...	80	80	...	250	250	96
Haiti	60—50	3,350	...	25	25	...	70	70	21
Jamaica	40	1,550	13	51	64	45	175	220	142
Lesser Antilles	50—60	1,200	...	75	75	...	200	200	167
Netherlands Antilles	50—60	183	...	115	115	...	275	275	1500
Puerto Rico	60	2,300	110	191	301	270	955	1,225	533
Trinidad and Tobago	60	742	...	80	80	...	315	315	425
		18,058	130	1,284	1,414	335	4,325	4,660	258
EUROPE									
Albania	50	1,400	6	25	31	30	50	80	57
Austria	50	6,980	2,187	867	3,054	8,638	3,056	11,694	1675
Belgium	50	8,900	53	3,897	3,950	186	11,660	11,846	1331
Bulgaria	50	7,629	175	340	515	742	1,470	2,212	290
Czechoslovakia	50	13,224	500	2,775	3,275	2,294	14,509	16,803	1270
Denmark	50	4,475	11	1,500	1,511	30	3,848	3,878	866
Finland	50	4,288	1,173	699	1,872	5,160	1,650	6,810	1588

Geographical Divisions	Type of Current, Cycles	Population (1000)	Installed Capacity 1000 Kw			Energy Production Million Kwhr			Kwh per Capita
			Hydro	Thermal	Total	Hydro	Thermal	Total	
EUROPE									
France	50	43,600	8,050	9,020	17,070	25,945	28,035	53,980	1238
Germany—East[13]	50	17,950	116	5,284	5,400	463	28,558	29,021	1617
West[3]	50	51,000	2,960	15,940	18,900	12,890	72,550	85,440	1675
Great Britain[4]	50	51,208	928	26,522	27,450	2,268	93,544	95,812	1871
Greece	50	8,000	118	379	497	525	1,071	1,596	200
Hungary[13]	50—42	9,800	8	1,077	1,085	38	5,252	5,290	540
Ireland—Ulster	50	1,375	100	225	325	395	750	1,145	833
Eire	50	2,895	188	352	540	670	900	1,570	542
Italy[5]	50	48,223	10,786	2,807	13,593	33,200	8,300	41,500	861
Luxembourg	50—60	312	1	215	216	4	1,165	1,169	3747
Netherlands	50	10,888	...	3,920	3,920	...	11,788	11,788	1083
Norway	50	3,462	4,727	142	4,869	23,185	190	23,375	6752
Poland	50	27,680	235	3,263	3,498	634	17,285	17,919	647
Portugal	50—60	8,837	680	215	895	2,006	160	2,166	245
Romania	50—42	17,490	100	1,150	1,250	470	4,500	4,970	284
Saar	50	992	10	620	630	25	2,428	2,453	2473
Spain	50	29,203	3,957	1,238	5,195	10,920	3,000	13,920	477
Sweden	50—60	7,316	5,290	1,340	6,630	24,440	2,680	27,120	3707
Switzerland	50	5,023	3,750	200	3,950	14,660	235	14,895	2965
USSR (total)[13]	50	200,200	8,370	34,425	42,795	29,050	162,950	192,000	959
Yugoslavia	50	17,799	708	712	1,420	2,914	20,126	5,040	283
Azores	50	290	...	12	12	...	30	30	103
Balearic Islands	50	460	...	15	15	...	35	35	76
Canary Islands	50	840	1	35	36	2	80	82	98
Cape Verde Islands	DC	150	...	15	15	...	45	45	300
Corsica	50	335	...	15	15	...	50	50	149
Crete	50	445	...	15	15	...	50	50	112
Cyprus	50—dc	527	...	50	50	...	105	105	199
Gibralter	50—dc	25	...	5	5	...	15	15	600
Iceland	50	160	77	29	106	419	21	440	2750
Maderia	50—dc	285	...	12	12	...	30	30	105
Malta and Gozo	50	314	...	25	25	...	75	75	239
		613,980	55,265	119,377	174,642	202,203	484,246	686,449	1118
AFRICA									
Algeria	50	9,700	175	350	525	375	575	950	98
Angola	50	4,317	15	25	40	30	65	95	22
Belgian Congo[6]	50	16,850	590	95	685	1,770	240	2,010	119
Egypt	50	23,250	6	550	556	20	1,500	1,520	65
Ethiopia[7]	50	19,500	10	25	35	25	80	105	5
French Africa[8]	50	26,250	55	115	170	260	165	425	16
Gambia	50	290	...	2	2	...	5	5	17
Ghana[9]	50—dc	4,691	...	80	80	...	250	250	53
Kenya	50	6,150	28	47	75	60	220	280	45
Liberia	50—60	2,760	3	10	13	12	35	47	17
Libya	50	1,350	...	35	35	...	110	110	81
Morocco (all)	50	10,200	301	94	395	820	130	950	93
Mozambique	50—dc	6,095	22	28	50	90	110	200	33
Nigeria	50	28,750	20	66	86	75	200	275	10
Rhodesia Federation	50	7,260	38	622	660	210	2,390	2,600	358
Sierra Leone	50	2,100	4	12	16	10	25	35	17
Somaliland[10]	DC	1,050	6	7	13	15	15	30	28
Sudan	50	11,250	...	21	21	...	50	50	4
Tanganyika	50—dc	8,456	20	18	38	65	75	140	17
Tangier	50	175	...	10	10	...	28	28	160
Tunisia	50	3,782	...	85	85	...	226	226	60
Uganda	50	5,593	60	20	80	120	25	145	26
Union of S. Africa	50	13,915	6	3,755	3,761	12	17,652	17,664	1269
Zanzibar	50	280	...	5	5	...	20	20	71
Misc. other		5,000	10	20	30	25	50	75	15
		219,014	1,369	6,097	7,466	3,994	24,241	28,235	129
ASIA									
Aden	50	800	...	37	37	...	97	97	121
Afghanistan	50—60	12,000	25	6	31	70	12	82	7
Burma	50—60	19,856	8	90	98	20	260	280	14
China[11, 13]	50—60	Est. 600,000	715	2,845	3,560	3,300	11,978	15,278	25
Formosa	60	8,150	351	142	493	1,760	480	2,240	275
Hong Kong	50—60	2,440	...	160	160	...	650	650	266
India	50	390,000	872	2,600	3,472	3,700	5,936	9,636	25
Indochina (Viet-Nam)	50	25,750	...	114	114	...	209	209	8
Iran	50—60	22,000	3	285	288	6	594	600	27
Iraq	50—dc	4,842	...	100	100	...	450	450	93
Israel	50	1,813	...	236	236	...	1,270	1,270	700
Japan	50—60	90,000	9,500	6,000	15,500	51,500	20,584	72,084	801
Jordan	50	1,400	...	10	10	...	21	21	15
Korea—North	50	8,800	2,050	100	2,150	6,200	300	6,500	739
South	60	21,600	120	275	395	450	666	1,116	52
Malay States[14]	50—dc	7,516	40	350	390	125	1,225	1,350	180
Pakistan	50	83,603	63	151	214	300	500	800	10
Saudi Arabia[12]	60	10,000	...	85	85	...	300	300	30
Syria and Lebanon	50—60	5,400	45	94	139	140	240	380	70
Thailand	50—dc	20,686	...	70	70	...	210	210	10
Turkey	50	24,797	150	695	845	151	1,634	1,785	72
Misc. other		5,000	50	50	100	125	125	250	50
		1,366,453	13,992	14,495	28,487	67,847	47,741	115,588	

WORLD POWER DATA

Geographical Divisions	Type of Current. Cycles	Population (1000)	Installed Capacity 1000 Kw Hydro	Installed Capacity 1000 Kw Thermal	Installed Capacity 1000 Kw Total	Energy Production Million Kwhr Hydro	Energy Production Million Kwhr Thermal	Energy Production Million Kwhr Total	Kwhr per Capita
OCEANIC & MISC. ISLANDS									
Australia and Tasmania	50—40	9,428	475	3,532	4,007	2,100	15,439	17,539	1860
Borneo	50	3,000	5	15	20	15	50	65	22
Ceylon	50	8,780	25	35	60	130	64	194	22
Fiji Islands	50	350	...	12	12	...	25	25	71
Guam	60	60	...	25	25	...	100	100	1667
Hawaiian Islands	60	600	30	296	326	100	1,250	1,350	2250
Indonesia	50	83,000	187	196	383	635	665	1,300	16
Madagascar	50	4,400	48	10	58	140	30	170	39
Mauritius	50	569	9	20	29	30	50	80	140
New Caledonia	50	115	15	10	25	60	25	85	739
New Guinea	50	2,050	6	4	10	30	15	45	22
New Zealand[13]	50	2,174	1,200	67	1,267	4,750	250	5,000	2300
Philippine Islands	60	22,265	85	300	385	435	900	1,335	60
Ryukyu Islands	60	810	...	56	56	...	200	200	247
Samoa	50	85	...	10	10	...	25	25	294
Misc. other		1,250	25	25	50	75	75	150	120
		138,936	2,110	4,613	6,723	8,500	19,163	27,663	199
TOTAL FOR THE WORLD—									
1956		2,708,776	118,196	264,309	382,505	515,645	1,161,941	1,677,586	619

[1] Including British Honduras.
[2] Including British, French and Surinam.
[3] Including West Berlin.
[4] Exclusive of Northern Ireland.
[5] Including Sicily and Sardinia.
[6] Including Ruanda Urundi.
[7] Including Eritrea.
[8] Both Equatorial and West.
[9] Formerly Gold Coast.
[10] Including British, French and Somalia.
[11] Including Manchuria.
[12] Including Yemen, Muscat, Oman, Bahrain, Kuwait and Qatar.
[13] Contains revision of data previously reported.
[14] Including Singapore.

COUNTRIES WITH GREATEST INSTALLED CAPACITY AND SUMMARY BY REGIONS

Country and Rank		Population (1000)	Installed Capacity Mw 1948	Installed Capacity Mw 1956	Per Cent Increase	Watts per Capita	Production per Kw Capacity, Kwhr
United States	1	168,091	69,615	136,996	96.8	815	4992
USSR	2	200,200	18,000	42,795	137.8	214	4487
Great Britain	3	51,208	13,300	27,450	106.4	536	3490
Germany—West	4	51,000	6,175	18,900	206.1	371	4521
France	5	43,600	10,910	17,070	56.5	392	3162
Japan	6	90,000	10,061	15,500	54.1	172	4651
Canada	7	16,081	9,404	15,280	62.5	950	5808
Italy	8	48,223	6,190	13,593	119.6	282	3053
Sweden	9	7,316	3,780	6,630	75.4	906	4090
Germany—East	10	17,950	4,500	5,400	20.0	301	5374
Spain	11	29,203	1,738	5,195	198.9	178	2679
Norway	12	3,462	3,000	4,869	62.3	1406	4801
Australia	13	9,428	2,280	4,007	75.8	425	4377
Switzerland	14	5,023	2,570	3,950	53.7	786	3771
Belgium	15	8,900	2,700	3,950	46.3	444	2999
SUMMARY BY REGIONS							
The Americas		370,393	85,947	165,187	92.2	446	4962
Europe, incl. all USSR		613,980	84,761	174,642	106.0	284	3931
Africa		219,014	3,615	7,466	106.5	34	3782
Asia		1,366,453	15,136	28,487	88.2	21	4058
Oceania		138,936	3,553	6,723	89.2	48	4115
Total world		2,708,776	193,012	382,505	98.2	141	4386
Communist countries[1]		921,972	31,267	64,979	107.8	70	4542
Other countries		1,786,804	161,745	317,526	96.3	178	4354

[1] USSR, Czechoslovakia, Bulgaria, Hungary, Romania, Poland, East Germany, Albania, Yugoslavia, China and North Korea.

WORLD POWER DATA

COUNTRIES WITH GREATEST ENERGY PRODUCTION AND SUMMARY BY REGIONS

Country and Rank		Population (1000)	Production Million Kwhr 1948	Production Million Kwhr 1956	Per Cent Increase	Production per Capita, Kwhr
United States	1	168,091	336,808	683,894	103.1	4069
USSR	2	200,200	62,500	192,000	207.2	959
Great Britain	3	51,208	46,536	95,812	105.9	1871
Canada	4	16,081	50,850	88,750	74.5	5519
Germany—West	5	51,000	31,332	85,440	172.7	1675
Japan	6	90,000	31,680	72,084	127.5	801
France	7	43,600	30,058	53,980	79.6	1238
Italy	8	48,223	23,413	41,500	77.3	861
Germany—East	9	17,950	14,500	29,021	100.1	1617
Sweden	10	7,316	14,268	27,120	90.1	3707
Norway	11	3,462	12,444	23,375	87.8	6752
Poland	12	27,680	7,512	17,917	138.5	647
Union of South Africa	13	13,915	9,356	17,664	88.8	1269
Australia	14	9,428	8,364	17,539	109.5	1860
Czechoslovakia	15	13,224	7,512	16,803	123.5	1270

SUMMARY BY REGIONS

Country and Rank	Population (1000)	Production Million Kwhr 1948	Production Million Kwhr 1950	Per Cent Increase	Production Per Capita, Kwhr
The Americas	370,393	406,156	819,651	101.8	2213
Europe, incl. all USSR	613,980	295,952	686,449	131.9	1118
Africa	219,014	11,885	28,235	137.6	129
Asia	1,366,453	46,915	115,588	146.4	85
Oceania	138,936	13,322	27,663	107.5	199
Total World	2,708,776	774,230	1,677,586	116.7	619
Communist countries	921,972	104,860	295,113	181.4	320
Other countries	1,786,804	669,385	1,382,473	106.5	774

COUNTRIES WITH GREATEST ENERGY PRODUCTION PER CAPITA—CAPACITY AND PRODUCTION FOR 1956

Country and Rank		Population (1000)	Installed Capacity, Mw	Production, Million Kwhr	Production Per Capita, Kwhr	Production per Kw Capacity, Kwhr
Norway	1	3,462	4,869	23,375	6752	4801
Canada	2	16,081	15,280	88,750	5519	5808
United States	3	168,091	136,996	683,894	4069	4992
Luxembourg	4	312	216	1,169	3747	5412
Sweden	5	7,316	6,630	27,120	3707	4090
Switzerland	6	5,023	3,950	14,895	2965	3771
Saar	7	992	630	2,453	2473	3894
New Zealand	8	2,174	1,267	5,000	2300	3946
Hawaiian Islands	9	600	326	1,350	2250	4141
Great Britain	10	51,208	27,450	95,812	1871	3490
Australia	11	9,428	4,007	17,539	1860	4377
Austria	12	6,980	3,054	11,694	1675	3829
Germany—West	13	51,000	18,900	85,440	1675	4521
Alaska	14	210	138	350	1667	2536
Germany—East	15	17,950	5,400	29,021	1617	5374

Patent Examiners Still at a Premium

The Patent Office is still desperately in need of engineers and scientists to serve as Patent Examiners, according to The New York Patent Law Association. The Association reports that while delays in the processing of patent applications in the Patent Office have been somewhat reduced during the past year, it still takes about ten months before a new patent application is first examined, and an average of 3½ years before a patent is issued.

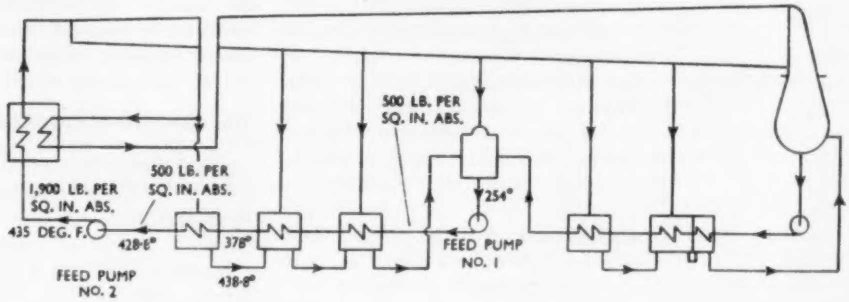
These delays create uncertainty as to the patent status of new products and processes and tend to slow down or defer their adoption by industry and their introduction to the public. This situation should be of general concern because it can handicap the larger corporation and can be critical for the individual inventor and the small businessman whose operations revolve around patented products and processes.

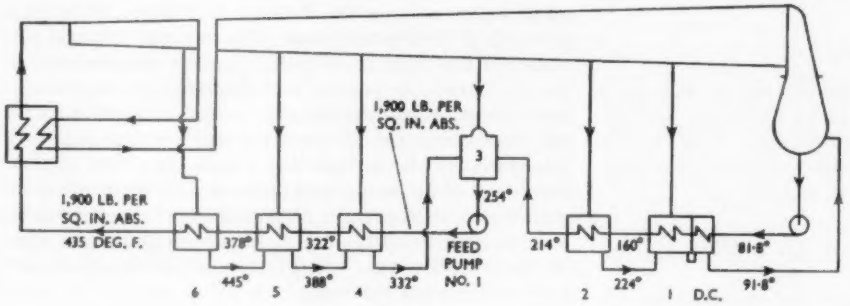
The key to this log jam is more Patent Examiners—technically trained men and women who will evaluate applications for patents in the technical fields constituting industry's latest frontiers to determine whether the new suggestions are novel and whether invention is involved. While there are openings in all areas, electrical engineers and electronics specialists are particularly needed.

Men and women holding college degrees in engineering or applied science, or a degree with a major in chemistry or physics, or with certain combined credits in these fields, are eligible for appointment as Patent Examiners, without examination, upon application to the Commissioner of Patents in Washington, D. C.

Under the revised salary schedule the minimum starting salary is $4,480 per year. Promotion to $5335 per year may be expected after three months' service, based solely on ability and work performance.

Split Pump versus Single Pump





The performance of single-pump and split-pump schemes in the non-reheat regenerative steam cycle is compared by an approximate analysis as against calculations. The study reveals the efficiency of the cycle is slightly greater for the split-pump arrangement. Detailed calculations for a typical reheat cycle show the same tendency.

By R. W. HAYWOOD*

FROM time to time discussion arises as to the optimum number and positioning of feed pumps in the feed train of a regenerative steam cycle, but the problem does not appear to have been treated hitherto on a satisfactory theoretical basis. Salisbury (1950)[1] applied approximate methods of calculation to assess the effect of altering the position of the boiler feed pump, but neglected the effect of the change in specific volume of the feed water with change in temperature. Kennedy and Hutchinson (1956) treated the problem in general terms by a method which appeared open to question on theoretical grounds. The present paper makes an approximate thermodynamic analysis of the relative performance of non-reheat systems employing the single-pump and split-pump arrangements, and reports on the results of more detailed calculations for both non-reheat and reheat cycles.

Symbols Used

$b = (h - T_c s)$ = Steady flow availability function
h = Enthalpy
J = Mechanical equivalent of heat
m = Mass of bled steam supplied to a heater per unit mass of feed water
$M = \Sigma m$ = Total mass of bled steam
n = Number of heaters
p = Pressure
Q_{in} = Heat supplied in the boiler
Q_{out} = Heat rejected in the condenser
r = Enthalpy rise of feed water in a heater
s = Entropy
T_c = Absolute temperature in condenser
t = Difference between inlet enthalpy of bled steam and saturation enthalpy of the condensed bled steam in a heater
$t' = (t + \rho)$ = Difference between inlet enthalpy of bled steam and enthalpy of exit drain water in a heater
v = Specific volume
W_{net} = Net internal work
W_0 = Work sent out from station
W_P = Work input to pump motors
W_T = Internal work output of turbine
W_W = Work input to feed water = enthalpy rise of feed water in the feed pumps

$\alpha = v_1/v_2$

$\beta = \left(1 - \frac{r}{t'}\right)^{n-1}$

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[1] An alphabetical list of references appears at the end of the article.

η_G = Combined efficiency factor for turbine external losses and generator losses

$\eta_i = W_{net}/Q_{in}$ = Internal thermal efficiency of plant

η_M = Product of pump motor efficiency and mechanical efficiency of pump

η_O = Overall thermal efficiency of plant

η_P = Internal isentropic efficiency of pump

ρ = Reduction in enthalpy of exit drain water below its saturation value at the pressure prevailing in a heater

Suffixes

F = Feed water at boiler inlet
S = Steam at boiler exit

Thermal Efficiency and Net Work

The thermal efficiency of a steam cycle is defined as the ratio of the net work output to the heat supplied. If only the internal isentropic efficiencies of the turbine and feed pump or pumps are considered and stray heat losses are neglected, the net work is given by:

$$\frac{W_{net}}{J} = (\Delta h_T - \Delta h_P) = (Q_{in} - Q_{out})$$

where Δh_T is the enthalpy drop of the steam in passage through the turbine, and is equal to the internal work delivered by the steam to the turbine shaft, while Δh_P is the enthalpy rise of the feed water in passage through the feed pump(s), and is equal to the internal work delivered to the water by the pump impeller.

These enthalpy quantities refer strictly to stagnation enthalpies, but this distinction will be ignored in the present work. All the above quantities are expressed in terms of unit mass flow of steam to the turbine. The thermal efficiency resulting from the use of the net work output defined above will be described as the internal thermal efficiency, η_i. Account will later be taken of the external losses in the turbine and pumps, and of the generator and pump motor efficiencies. The thermal efficiency expressed in terms of the net work sent out will be described as the overall thermal efficiency, η_O.

The Non-regenerative Cycle

The enthalpy rise of the feed water in passage through the feed pump is given by:

$$\Delta h_P = \frac{\int v dp}{J\eta_P} \doteq \frac{v_m \Delta p}{J\eta_P}$$

where v_m is the mean specific volume of the water and Δp the pressure rise in the pump.

Since the specific volume increases with temperature, the work input to the pump is least, and the thermal efficiency is greatest, when the water is compressed at the lowest possible temperature; that is, at the condenser, before any heat is added.

The Completely Reversible Regenerative Cycle

For a completely reversible regenerative cycle with an infinite number of heaters the internal thermal efficiency is given by:

$$\eta_i = \frac{W_{net}}{Q_{in}} = \frac{b_S - b_F}{h_S - h_F}$$

It should be noted that the subscript F refers to the state of the feed water at the true final feed temperature, namely, that at boiler inlet; this isn ot the same as the temperature at exit from the last heater if there is a pump between the last heater and the boiler. Thus, for a given final feed temperature, the internal thermal efficiency of the plant is independent of the arrangement of the feed pump or pumps in the system, so long as this arrangement is compatible with complete reversibility for all processes in the plant, the respective internal work quantities for the turbine and pumps may vary slightly according to the pump arrangement, but their difference will always be the same. A discussion of the criteria for complete reversibility of all processes is outside the scope of the present paper. In any case, reversible cycles are only of academic interest.

The Irreversible Regenerative Cycle with a Finite Number of Heaters

For a reason which will shortly become apparent, there is a thermodynamic advantage in putting the compression work into the feed water at a higher point in the feed train. Against this advantage must be offset the effect of the increase in the work of compression arising from the increased specific volume of the water at the higher temperature. On the relative magnitudes of the effects of these two opposing tendencies depends the thermodynamic superiority or inferiority of the split-pump scheme over the single-pump scheme in a feed system with a finite number of heaters.

Single-pump and Split-pump Arrangements in the Non-reheat Cycle

An approximate analysis is first made for a non-reheat cycle with n surface feed heaters with the drains cascaded, and the alternative pump arrangements shown in Fig. 1 are compared. These are:

System A. Single-pump Scheme. A single pump (pump No. 1) combines the duties of condenser condensate extraction pump and boiler feed pump.

System B. Split-pump Scheme. A condensate extrac-

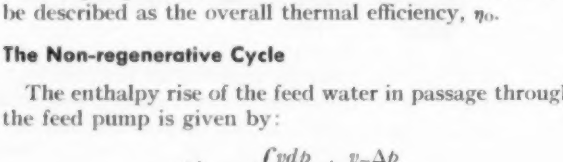

Fig. 1a—Simple single pump in non reheat cycle serves as condensate and boiler feed pump

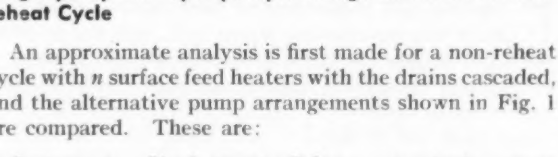

Fig. 1b—Separate condensate extraction pump moves the condensate to boiler feed pump section for final pumping

tion pump (pump No. 1) delivers to a pressure sufficient to prevent ebullition at the suction of the main boiler feed pump (pump No. 2), which is placed after the nth heater as shown in Fig. 1b.

These pump arrangements have been chosen for the sake of simplicity and it is not suggested that they would be adopted in practice, but the method of calculation can readily be applied to more practical systems.

For the purpose of analysis certain simplifying assumptions are made and their effects considered later. To overcome, though not to neglect, the complication resulting from the variation in the enthalpy of water with varying pressure at a given temperature, it is assumed that the exit enthalpy (and not the exit temperature) of the feed water leaving each heater but the nth is the same in both systems A and B. It is also assumed that the bled steam condition at the inlet to each heater is the same in the two cases; the heater terminal temperature difference is consequently not quite the same in the two cases, and the effect of this is discussed later.

With the same final feed temperature at boiler inlet, the principal effect of changing the arrangement from A to B is then a decrease in enthalpy rise in the nth heater, as a result of the introduction of pump No. 2 between this heater and the boiler, and an increase in enthalpy rise in the first heater as a result of the reduction in enthalpy rise in pump No. 1. Per unit mass flow to the turbine, this brings about a relatively large reduction in the steam quantity bled to the nth heater, and consequential small increases in the steam quantities bled to all the other heaters as a result of the reduced drain quantity passing through them, whilst there is a further increase in the steam quantity bled to the first heater as a result of the increased enthalpy rise of the feed water in this heater.

Since the higher the pressure at which steam is bled the greater is the reduction in turbine work output due to bleeding, a given reduction in steam quantity bled to the nth heater results in a greater increase in turbine work output than results from a similar reduction in bled steam quantity to a lower heater. Thus the thermodynamic advantage of putting the pump work into the feed water at a higher point in the feed train is clearly seen. It remains to be seen, however, to what extent this increase in turbine work output is offset by the increased pump work input resulting from the increased specific volume of the feed water at the higher temperature. If there is an increase in the total quantity of steam bled to all heaters as a result of the above changes for the individual heaters, then the steam flow rate to the condenser will be reduced, and so the heat quantity rejected in the condenser will also be reduced; the net work, W_{net}, and the internal thermal efficiency will thus be increased in spite of an increase in total pump work input. The effect can be examined analytically by using approximate methods described in the author's paper on the regenerative cycle (Haywood 1949).

Approximate Analysis

The method is based on the fact that the difference, t, between the enthalpy of the bled steam and the saturation enthalpy of the condensed bled steam, is very nearly the same for all heaters, and in the analysis is assumed to be the same. It was shown in the author's paper that the optimum condition for maximum efficiency occurs, to a first approximation, when the enthalpy rise, r, of the feed water in a heater is the same for all heaters. Consequently if, with surface heaters with the drains cascaded, all the heaters have approximately the same terminal temperature differences, the difference between the enthalpy of the inlet bled steam and the enthalpy of the exit drain water will be very nearly the same for all heaters and will equal $t' = (t + \rho)$ where ρ is the reduction in enthalpy of the exit drain water below its saturation value at the pressure prevailing in the heater. With this data, an energy balance can be drawn up for each heater in turn, starting at the nth, to evaluate the changes in bled steam quantities resulting from the change from system A to system B. With the type of feed train chosen, unit mass flow rate to the turbine corresponds to unit mass flow rate of feed water through all the heaters and, in the analysis, all flow and energy quantities relate to unit mass of steam supplied to the turbine. Work is expressed in thermal units.

Under the above conditions, with a constant final feed temperature at boiler inlet, the reduction in enthalpy rise in the nth heater in system B, when compared with system A, is equal to the enthalpy rise, Δh_2, of the feed water in pump No. 2. An energy balance for the nth heater then shows that the resulting change in steam quantity bled to this heater is given by

$$\delta m_n = \frac{\Delta h_2}{t'}$$

This reduction in steam quantity bled to the nth heater is reflected in the $(n - 1)$th heater by an equal reduction in the quantity of drain water passing through the latter, and an energy balance for the $(n - 1)$th heater shows that this results in an increase in the steam quantity bled to this heater of

$$\delta m_{n-1} = +\frac{r}{t'} \cdot \frac{\Delta h_2}{t'}$$

The total change in steam quantity bled to these two heaters is thus given by

$$\delta m_n + \delta m_{n-1} = -\frac{\Delta h_2}{t'}\left(1 - \frac{r}{t'}\right)$$

This quantity is the reduction in the quantity of drain water passing through the $(n - 2)$th heater, and by repeating the above calculation progressively down to the first heater it is seen that the total change in steam quantity bled to all n heaters, on account of the introduction of pump No. 2 between the nth heater and the boiler, is given by

$$\sum_{n}^{1} \delta m = -\frac{\Delta h_2}{t'}\left(1 - \frac{r}{t'}\right)^{n-1} \qquad (1)$$

The change from system A to system B results in a change, Δh_1, in the enthalpy rise in pump No. 1. Under the conditions cited above, the resultant change in the enthalpy rise of the feed water in the first heater causes a further change in the steam quantity bled to this heater, of magnitude

$$\delta m_1 = -\frac{\Delta h_1}{t'} \qquad (2)$$

where Δh_1 is in fact negative, so that δm_1 is positive.

The total change in steam quantity bled to all the heaters in changing from system A to system B is thus given by adding equations (1) and (2) to give

$$\Delta M = -\left[\frac{\Delta h_1}{t'} + \frac{\Delta h_2}{t'}\left(1 - \frac{r}{t'}\right)^{n-1}\right]$$

Per unit mass of steam supplied to the turbine stop valve, the steam flow to the condenser is thus reduced by an amount equal to ΔM and, since the heat rejected in the condenser per unit mass of steam is, to a first approximation, equal to t, and the reduction in heat quantity rejected in the condenser is equal to the increase in net work, ΔW_{net}, there is an increase in net internal work resulting from the change from A to B which is given by

$$\Delta W_{net} = -\frac{t}{t'}\left[\Delta h_1 + \left(1 + \frac{r}{t'}\right)^{n-1}\Delta h_2\right] \qquad (3)$$

The factor $\left(1 - \frac{r}{t'}\right)^{n-1}$ by which Δh_2 is multiplied gives an inverse measure of the thermodynamic advantage of putting the pump work into the feed water at a higher point in the feed train, in that the smaller this factor the greater is ΔW_{net}.

If the pressure rise in pump No. 2 is Δp_2, and if both pumps have an internal isentropic efficiency of η_P, then Δh_1 and Δh_2 are given by

$$\Delta h_1 = -\frac{v_1 \Delta p_2}{\eta_P J} \text{ and } \Delta h_2 = \frac{v_2 \Delta p_2}{\eta_P J} \qquad (4)$$

where v_1 and v_2 are the mean specific volumes of the feed water passing through the respective pumps. Per unit mass of steam supplied to the turbine stop valve, the increase in net work in changing from system A to system B is thus

$$\Delta W_{net} = \left[\frac{v_1}{v_2} - \left(1 - \frac{r}{t'}\right)^{n-1}\right]\frac{t}{t'} \cdot \Delta h_2$$

$$= (\alpha - \beta)\frac{t}{t'} \cdot \Delta h_2 \qquad (5)$$

Whether the net work is greater or less in scheme B than in scheme A depends on the relative magnitudes of α and β. If β is less than α the thermodynamic advantage of putting the compression work into the feed water at a higher point in the feed train will more than compensate for the resulting increase in compression work.

The Relative Magnitudes of α and β

Both α and β are principally dependent on the final feed temperature, and are little affected by variation of the operating pressure. A fairly close estimate of the quantities for typical conditions may therefore be made in terms of the final feed temperature. v_1 and v_2 may be taken as the saturation specific volumes at condenser temperature and final feed temperature respectively, and the value of α so calculated is shown in Fig. 2 for a vacuum of 29 in. mercury (barometer, 30 in). If, for the purpose of this approximate estimate, the feed water enthalpy at inlet to the first heater is assumed to be 50 Btu per lb, and r is taken to be 70 Btu per lb, then the final feed temperature corresponding to any chosen number of heaters can be determined approximately, and β can be calculated in each case if a value of t' is assumed. The points on the dotted curve in Fig. 2 show such calculated values of β for 4, 5, 6, and 7 heaters respectively, and a value of $t' = 1000$ Btu per lb.

The two curves for α and β are closely parallel to each other over the entire range of feed temperature shown, α being a practically constant small amount greater than β, so that ΔW_{net} in equation (5) will always be positive in this range. This means that the net internal work output of the split-pump scheme will be greater than that of the single-pump scheme for a given heat input.

That β is relatively insensitive to variations of r and t' is seen by calculating the value of β for the same total enthalpy ranges as before, but keeping the number of heaters constant at five over the entire range, so that r varies. With suitable allowance for the consequent variation of t', the calculated value of β is shown as the full curve in Fig. 2. The difference between α and β is still retained, though slightly reduced at the higher temperatures. However, it should be pointed out that the dotted curve is more likely to represent practical conditions, since the higher the final feed temperature for which the plant is designed the greater will be the number of heaters.

Effect on the Net Work Sent Out from the Station

W_{net} is the difference between the internal work output of the turbine and the work quantity put into the feed water in the pumps, so that in the above evaluation of ΔW_{net} no account has been taken of the effect of turbine external losses and of the efficiencies of the generator and pump motor, nor of the mechanical efficiency of the pump. This effect must be evaluated before the overall effect on the work sent out from the station can be assessed. The following relations hold

$$W_{net} = W_T - W_W \qquad (6)$$

$$W_W = \eta_M W_P \qquad (7)$$

$$(W_O + W_P) = \eta_G W_T \qquad (8)$$

It can readily be shown from equations (6), (7), and (8) that the change ΔW_O in work sent out is related to ΔW_{net} as already evaluated, by the equation

$$\Delta W_O = \eta_G \Delta W_{net} - \left[\frac{1}{\eta_M} - \eta_G\right]\Delta W_W \qquad (9)$$

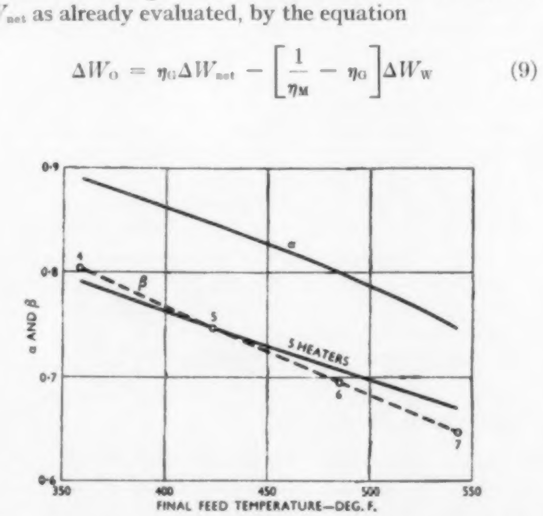

Fig. 2—α and β compared. The numbers in the β curve relate to number of heaters

where

$$\Delta W_W = (\Delta h_1 + \Delta h_2) = \Delta h_2\left[1 - \frac{v_1}{v_2}\right] \quad (10)$$

Equations (4), (5), (9), and (10) give all the information necessary for the overall station efficiencies for schemes A and B to be compared, since they enable the difference between the work sent out from the station in the two cases to be determined. The equations are best used as they stand, but they can be combined into the single equation given below for ΔW_0 in terms of Δp_2

$$\Delta W_0 = \left[\eta_G\frac{t}{t'}(\alpha - \beta) - \left(\frac{1}{\eta_M} - \eta_G\right)(1 - \alpha)\right]\frac{v_2 \Delta p_2}{\eta_P J} \quad (11)$$

Evaluation by Approximate Analysis, and by Detailed Calculation, for Specific Conditions

To relate the analysis to a specific case, and to check by detailed calculation the answer so obtained, the following conditions were chosen:

Steam conditions at tubine stop valve..............	1500 lb per sq in abs/ 1000 F
Condenser vacuum.........	29 in. of mercury (barometer, 30 in.)
Final feed temperature (at boiler inlet).............	450 F
Number of heaters.........	5
Intermediate feed pressure in system B...............	600 lb per sq in abs
Internal isentropic efficiency of pumps...............	75 per cent

For these conditions a turbine expansion line was assumed, and detailed calculations were made for systems A and B for the conditions laid down as the basis for the foregoing analysis. For the purpose of this comparison the final feed pressure was taken to be equal to 1500 lb per sq in abs. The bled steam pressures in system A were chosen to give approximately equal enthalpy rises in all heaters and heater terminal temperature differences of 10 F at feed water outlet. The temperature difference between the exit drain water and the inlet feed water was taken as 5 F for all heaters. The bled steam condition, the exit enthalpy of the drain water from each heater, and the exit enthalpy of the feed water from each heater but the last, were kept the same in system B as in system A. The results of these detailed stage-by-stage calculations are summarized in Table 1, where the value of ΔW_{net} so determined is compared with the value calculated from equation (5).

TABLE I.—RESULTS OF CALCULATIONS

		System A	System B	Change from A to B
Enthalpy rise of feed water in pump No. 1, Btu per lb		5.935	2.376	$\Delta h_1 = -3.559$
Enthalpy rise of feed water in pump No. 2, Btu per lb		..	4.284	$\Delta h_2 = +4.284$
Total work of compression, Btu per lb		5.935	6.660	$\Delta W_W = +0.72$
ΔWnet	From detailed calculations	..	..	+0.399
	From equation (5)	..	..	+0.389

The agreement between the values of ΔW_{net} obtained by detailed calculation and from equation (5) is seen to be good. Of particular interest is the fact that, in spite of the negative work in the cycle being greater in system B than in system A, the net work and therefore the thermal efficiency of B is greater than that of A. The reason for this was seen in the discussion of equation (5) and Fig. 2. It is further illustrated by showing the calculation of ΔW_{net} from equation (3), although equation (5) would usually be used. Using the mean values for r, t, and t' from the detailed calculations (in the absence of detailed calculations these can be estimated readily to sufficient accuracy) equation (3) gives

$$\Delta W_{net} = -\frac{t}{t'}\left[\Delta h_1 + \left(1 - \frac{r}{t'}\right)^{n-1} \Delta h_2\right]$$

$$= \frac{930}{1012}\left[3.559 - \left(1 - \frac{75.5}{1012}\right)^4 + 4.284\right]$$

$$= \frac{930}{1012}(3.559 - 0.7332 \times 4.284)$$

$$= \frac{930}{1012}(3.559 - 3.141) = 0.384$$

Thus although Δh_2 is greater in magnitude than Δh_1, the factor $\left(1 - \frac{r}{t'}\right)^{n-1}$ by which Δh_2 is multiplied results in ΔW_{net} being greater for system B than for system A: that is, the thermodynamic advantage of putting the work into the feed water at a higher point in the feed train more than offsets the effect of the increase in pumping work arising from the greater specific volume of the water at the higher temperature. It may be noted that, for the conditions chosen, the magnitudes of α and β are respectively 0.8320 and 0.7332: these are in close agreement with the approximate values read from Fig. 2 at a final feed temperature of 450 F.

In terms of the net work sent out from the station, W_0 is greater for system B than for system A by an amount ΔW_0, given by equation (9). Using the value of ΔW_{net} obtained by detailed calculation, and taking η_G = 96 per cent and η_M = 93 per cent, this gives

$$\Delta W_0 = 0.96 \times 0.399 - 0.1153 \times 0.725 = 0.383 - 0.084$$
$$= 0.299 \text{ Btu}$$

Thus, in spite of an increase of pumping power for system B of 0.725 Btu, or about 0.17 per cent of the work sent out, there is an *increase* of about 0.07 per cent in the work sent out. These quantities are small but in the present context it is the effect that is significant, rather than its magnitude.

An Alternative Basis of Comparison

It might be questioned whether the basis chosen above for the comparison of the two systems, which has been devised in order to render an analytical solution possible, is the best that can be made. Ideally, the optimum conditions for both systems should be determined individually, and then the performances of the two systems

at their respective optimum conditions compared. This would be far too tedious and is not justified by the nature of the problem. In practice, the two systems would probably be designed for the same heater terminal temperature differences, rather than for the same feed water and drain enthalpies at exit from each heater but the last. A careful detailed calculation was therefore made on this alternative basis keeping the bled steam conditions the same for all heaters but the last; the bled steam pressure to the last heater was reduced for system B in order to keep the difference between the bled steam saturation temperature and the feed water outlet temperature unaltered.

On this alternative basis of comparison, system B still shows a gain over system A, but the increase in W_{net} is reduced from 0.399 Btu (0.09 per cent), to 0.117 Btu (0.03 per cent), while ΔW_0 is reduced from 0.299 to 0.029 Btu. That the original basis of comparison favours B more than does the new basis is explained by the fact that on the former basis the last heater, which uses the highest grade steam, carries all the reduction in feed water enthalpy rise due to the introduction of pump No. 2, whereas on the new basis all the heaters are affected by the change in enthalpy of the feed water with pressure. It is interesting to note, however, that on either basis the split-pump scheme shows a gain over the single-pump scheme, in spite of the smaller pumping power in the latter.

As a point of academic interest only, it might be noted that detailed calculation shows that an arrangement having individual pumps between each heater gives the best performance of all, although the margin is small and the pumping power is greater than in the other two arrangements.

The Reheat Regenerative Cycle

When reheating is used, the same two opposing factors as are experienced in the non-reheat cycle influence the change in efficiency resulting from a change in pump position. It is not profitable to attempt to apply an approximate method of calculation to the reheat cycle, and an exact determination of the effect of changing the pump position must be made by very careful detailed calculation. Such a detailed calculation has been made in collaboration with Mr. B. Wood of Merz and McLellan for the typical practical conditions illustrated on p 49. The calculations related to a plant operating with initial steam conditions of 1500 lb per sq in abs/1000 F, reheating to 1000 F, and a vacuum of 28.9 in. mercury (barometer, 30 in.).

For the split-pump scheme of page 49 the reheat tapping point coincided with the highest heater tapping point. In order that the two calculations should be on a comparable basis the reheat pressure was kept the same for the single-pump scheme of page 49 although this involved an impracticable position for the reheat point, in that it was then just above the highest heater tapping point. The final feed pressure was taken as 1900 lb per sq in abs in both cases, with an intermediate feed pressure of 500 lb per sq in abs for the split-pump scheme. In both cases the calculations were based on a terminal temperature difference of 10 F between the bled steam saturation temperature and the feed water outlet temperature in all heaters, and the exit drain water temperature was taken as being equal to the bled steam saturation temperature. It is of interest that the split-pump scheme still showed a small gain over the single-pump scheme although the difference was so small as to be negligible for all practical purposes, being 0.02 per cent on net work and less than 0.01 per cent on work sent out.

Conclusions

The paper has given an analytical and detailed comparison of the performance of single-pump and split-pump schemes, and has explained why the latter gives the slightly higher thermal efficiency. Although this advantage of the split-pump scheme is so small as to be practically negligible, it is reinforced by other advantages of a practical and economic nature. A practical advantage is the fact that, with the split-pump arrangement, not all the heaters are subjected to full boiler pressure. A point in favor of the single-pump scheme is the provision of only one pump, with an input smaller than the combined inputs of the two pumps in the split-pump scheme. However, Kennedy and Hutchinson (1956) have estimated that for 120-Mw units, although the single pump and motor might cost some 30 per cent less than the two pumps and motors in the split-pump arrangement, the cost of the heaters might be 50 per cent higher when using a single pump, on account of the fact that the heaters are all subjected to full boiler pressure; they consequently estimated that the total expenditure for a 120-Mw unit would be at least £30,000 higher for the single-pump scheme. When there is added to this the continuous small saving on fuel, the split-pump scheme is seen to be preferred on both counts.

Throughout the paper reference has been made to the true final feed temperature at boiler inlet. Only in terms of this temperature is the efficiency of a completely reversible cycle the same for all possible alternative arrangements which involve no irreversibilities. In spite of the fact that this is the only true final feed temperature, it has been customary, for obvious practical reasons, for makers' guarantees to be given in terms of the feed temperature at exit from the last heater. If this temperature were kept the same for systems A and B, then the advantage would be still more in favor of the split-pump scheme, because its true final feed temperature is greater than that of the single-pump scheme by an amount equal to the temperature rise in pump No. 2, which is of the order of 4 F for the conditions quoted. The additional gain in thermal efficiency consequent on the higher mean temperature of heat reception is quite artificial, however, since it results from a basis of comparison which is unscientific.

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Editor's Note:

The very well accepted Abstracts From the Technical Press—Abroad and Domestic will be run from time to time as copy becomes available

Energy in the amounts of 30,000 times man's present needs becomes available daily to the earth in the form of solar energy. Obviously this vast supply is a constant challenge to man's ingenuity to devise ways to put it to use. Here is an excellent summation of the present possibilities and the future outlook.

Power From The Sun

By WILLIAM T. REID* Battelle Memorial Institute

SOLAR energy as a source of power has been a frequent subject of discussion among technologists for a great many years. The first known steam engine powered by the sun was built in France almost a century ago, and there have been many attempts since then to devise practical power systems using sunlight in place of mineral fuels. Recently, pessimistic predictions concerning the reserves of mineral fuels and the realization that man's demand for energy is growing at a prodigious rate have touched off a new interest in solar power. Part of this interest possibly stems also from a realization that research today is capable of accomplishing tasks considered impossible only a few years ago. It is likely, too, that the development of nuclear power systems over a span of less than a decade has led to the belief that practical solar-powered systems also may be devised.

Although our reserves of coal are less limited than those of oil and gas, some pessimistic observers are predicting already that the expected growth in population and in the per-capita demand for energy will see our mineral fuels depleted within a few more generations. It seems unlikely, however, that the costs of solar-produced energy could be competitive with mineral fuels or with nuclear-produced power, even when the mineral fields might be far more costly than they are today. Fuel-rich areas are not likely prospects for solar-produced power within the foreseeable future. Nevertheless, areas exist in this country, and particularly abroad, where conventional fuels are unobtainable or costly, and where solar energy might be utilized successfully.

The only truly inexhaustible source of energy available to man, the sun, nevertheless has serious limitations as a power source. Its availability over only a part of the day, the unpredictable aspects of weather, and the relatively low density of the energy received at the earth's surface all pose serious problems to man's utilization of the sun's output. These, coupled with inefficient and expensive storage devices for electrical energy have prevented any serious attempts as yet at producing even moderate-scale useful electrical energy from solar radiation. With recent advances in technology, however, the problem of converting solar energy into useful power is worth a new look.

The Problem of Collection

Although solar energy is there for the taking, many serious scientific and engineering problems are involved in collecting it. Not the least of these is the relatively low level of radiation received from the sun. Thus, although the total solar energy intercepted by the earth is tremendous, amounting in three days to the equivalent of the total energy to be produced by consuming all our mineral fuels and burning all our forests, the intensity of radiation per square foot is not great compared with man-made devices. The solar constant, or the energy falling on one square centimeter with normal incidence, is 1.92 cal per min. This is equivalent to 425 Btu per sq ft per hr, or about one five-hundredth of the rate of heat transfer in a modern pulverized-coal-fired boiler. Expressed another way, one square foot of unobstructed sunlit area receives 125 w of power.

Assuming that 80 per cent of this energy is transmitted through our atmosphere, and that we could utilize it with an efficiency at the gathering point of 10 per cent, 10 w would be available per square foot. This is an extremely low rate. It points up the need for large heat-receiving surfaces to produce appreciable quantities of electricity. For instance, a 1000-kw solar-power-energized generator would require 100,000 sq ft of surface to produce power at that rate in direct sunshine. If the sunshine were available only 8 hr per day every day, and if a storage battery could be made with twice the capacity and with a 50 per cent efficiency, the surface required would be 600,000 sq ft to provide round-the-clock output. This is roughly equivalent to 14 acres of heat-receiving surface for a 1000-kw station.

It is evident that a serious problem exists in producing such a large expanse of energy-collecting surface. Not only would this be expensive to fabricate, it would also be relatively costly to install and maintain. Increasing the efficiency of collection, conversion, and storage to reduce this area to a more reasonable size offers a real challenge to research.

The Problem of Energy Storage

Any extensive application of solar energy to produce useful power must involve an efficient reservoir for energy. At present, we have no satisfactory methods for storing energy on a large scale. Our entire electrical-generating facilities, for instance, are geared to producing power at the exact instant it is consumed. Electrical energy can be said literally to have a zero lifetime. Only in standby service are storage batteries used, where their cost and relative inefficiency are tolerable. Dams to store water during spring floods represent man's largest facility for storing potential energy. Even here, in many cases, these are intended more for flood control than for energy.

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Electrical energy generated from sunlight stands little chance of becoming important on any extensive scale until efficient and low-cost energy reservoirs can be devised. These would need a capacity sufficient at least to provide 24-hr electrical service when being charged only for 8 hours or so each day. Thus, the capacity of such storage systems would have to be comparable roughly to twice the entire output of the generating system. Where the sun might be obscured for several days at a time, the problem of storage would be difficult indeed. This is almost as formidable a problem as the efficient capture of solar power, yet it must be solved before solar energy can be applied to anything other than relatively small-scale projects. Residential heating, a field already explored by many investigators as a means of utilizing solar energy, has this same problem to an exaggerated degree. No suitable economical solution has been found as yet, although many ingenious methods have been proposed and tried.

The Application of Solar Energy

Much of the problem in utilizing solar energy today lies in identifying applications where this fuel-free source of power is best suited. Such applications might include the generation of power to pump water in desert areas, to provide the energy to convert saline water to potable water, to power industrial processes where the energy demand is only reasonably high but controllably intermittent, or to supplement the output of small hydroelectric plants so as to conserve dammed water. These applications are all free from the need for an energy storage system, and thereby are simpler than the cases where solar power might be used on a 24-hr basis.

The most promising applications would be in areas where fuel is not ordinarily available or where the transportation of fuel would be extraordinarily difficult. Arid regions, remote mountainous areas, and small barren islands would be typical of such locations.

For cases where some storage of electricity might be permitted, but where supply problems might make refueling almost impossible, solar energy could be useful. These might include radio beacons for navigational purposes, unmanned weather stations, some military operations, and such unusual cases as providing the electrical energy needed to power the telemetering transmitters on a satellite. These are special-purpose cases, however, that probably will not be important commercially.

Attention is needed for cases where solar power could be used today if technical and economic problems could be solved. On the basis that solar-produced power would be utilized in areas where existing energy sources are unavailable, the problem of cost is less important. Thus, the main consideration here would be the solving of technological problems where cost cannot be ignored, but where there would be no competition with low-cost electrical energy produced more conventionally.

Of the many problems to be solved here, the most important seem to involve three points: (1) the most promising method of converting solar power into electrical energy; (2) the most feasible method of collecting this low-level energy over the wide area comprising the energy converter; and (3) the temporary storage of this energy to allow for the diurnal cycle and for unfavorable weather. These factors are interdependent. All three of them should be considered as equally important. Although the storage problem might not apply in all cases it will unquestionably receive passing attention.

Converting Solar Power Directly into Electrical Energy

Of all the methods of producing electrical energy directly from sunlight proposed so far, those based on photochemical processes and on solid-state devices look most promising.

Photochemical Processes

Photochemical processes involve the conversion of the photons in sunlight into chemical energy, rather than using the thermal energy in the sun's radiation. That is, to produce chemical products rather than heat. These chemical products, in turn, would then be converted into electricity by a suitable cell.

For example, some fluorescing dyes, such as rhodamine-B in alcohol, develop a potential of a hundred millivolts or more when irradiated by visible light in cells of extremely simple construction. Probably a photochemically modified oxidation-reduction reaction takes place. Little information is available on the quantum efficiency of such arrangements or the energy that could be converted by them. However, this could well be an extremely fruitful field to explore, for it offers the additional advantage of producing an intermediate compound that might be stored until its energy would be needed. In other words, it might produce an "electrolyte" that would be consumed as required, the end product serving as the raw material for further radiation.

Other systems utilizing oxidation-reduction involve the thionine-iron scheme, where a potential difference occurs between illuminated and darkened legs of a cell. Although this particular system has been discarded as impractical, undoubtedly other more successful systems could be turned up by an intensive search coupled with intelligent experimentation.

Another process of great interest is the photochemical decomposition of water into hydrogen and oxygen in the presence of ceric and cerous ions. Although of low quantum efficiency in its present form, such a system would be extremely interesting if the overall efficiency could be improved. For instance, one can imagine the production of hydrogen and oxygen in a photochemical system, and the temporary storage of these gases in Hortonspheres or other pressurized containers, or even in underground formations. Fuel cells such as the Bacon cell might then convert these gases into direct current as required. Because so many electrochemical processes require direct current, this might even offer an opportunity of establishing electrochemical plants in areas where power has not been available but where sunshine is abundant.

Considerable work has been done already on this process, with results thus far that are not encouraging. Nevertheless, the potentialities are sufficient to warrant continued interest.

Solid-State Devices

Both thermoelectric and photovoltaic devices can be used for generating electricity directly from sunlight. The former converts the thermal energy in sunlight into electricity by heating the hot junctions of thermocouples; the latter captures photons in a semiconductor, thereby producing an electrical current.

Great advances have been made in the past few years in developing new thermoelectric materials with high

thermoelectric force and moderate resistivity. Intermetallic compounds, such as bismuth telluride, for instance, may provide a potential as high as 200 microvolts per degree centigrade. With such materials, assuming a temperature difference between the hot and cold junctions of 50 F, a single cell would produce a voltage of less than 0.006 v, but these cells could easily be connected in series to provide more useful potentials. The overall efficiency of such thermocouples at present may not exceed five per cent, but this can be expected to improve. The efficiency of such a device is dependent upon the materials used in constructing the device, the most promising materials having been developed only recently. The thermoelectric generator in its present state probably would be less than half as efficient as the photovoltaic cell. Also, it might require some sort of collection system for concentrating the energy to get higher temperatures.

Possibly of greatest practical importance immediately is the solar battery comprising a semiconductor to convert light directly into electricity.

Intensive research on semiconductors over the past ten years has made the direct conversion of solar energy to electrical power by use of photovoltaic means appear very promising in every field except cost. The ultimate usefulness of such a device is governed by several factors, among which are efficiency, difficulty of producing a reasonable device, and the overall economy of the device. Some of these factors are fairly well worked out; others can be estimated reasonably well, based upon present trends and experience in the field, while a few must be estimated only approximately because some of the research is in its infancy.

The efficiency of photovoltaic cells is usually defined as the ratio of electrical power output, which is the product of output current and voltage, to the incident solar energy. The incident energy covers a wide band in the spectrum of electromagnetic radiation and includes the ultraviolet, the visible, and the infrared regions. The peak is in the near infared region of the spectrum. One way to characterize a semiconductor is by defining the wave length of radiation it will absorb, because this factor will determine both the output voltage and current from the photovoltaic cell. Cells which absorb in the visible and ultraviolet regions of the spectrum and not in the infrared will tend to have higher output voltage but lower output current. Those which absorb over a broader band of frequencies including part of the infrared region tend to have higher output current but lower output voltage. Those which absorb appreciably in the far infrared region of the spectrum have both low output voltage and output current because of the other factors and, therefore, have low efficiency. Hence, the output power is dependent upon the region of the spectrum in which the device absorbs energy. Because of two competing factors—namely current and voltage—the maximum output power can be shown to be available when the semiconducting material which comprises the photovoltaic cell absorbs energy only to wave lengths as long as those in the near infrared region of the spectrum. Since the most efficient devices do not absorb all the incident energy, their efficiency is less than 100 per cent.

The efficiency of these devices is also dependent upon the amount of incident energy. A certain amount of power is dissipated within the cell practically independent of the incident energy and, therefore, the efficiency would be higher on clear days than on cloudy days. Also, higher-voltage units have higher internal losses and tend to be slightly less efficient.

Taking all of the above factors into consideration, it can be shown that the theoretical maximum efficiency for the type of devices presently in use and for presently known semiconductors is between about 20 per cent and 27 per cent, depending upon the specific semiconductor used to construct the device. Silicon solar cells should have about 19 per cent maximum efficiency. Because of reflection losses and other factors which reduce the amount of energy absorbed, the highest efficiency reported experimentally to date is about 11 per cent. Some of the newer semiconductor materials, such as the intermetallic class of compounds, offer the possibility of constructing devices with theoretical efficiencies somewhat greater than 25 per cent.

The most efficient devices reported to date have been constructed from silicon, mainly because of the advanced state of the art in producing this material. A single crystal with rather closely controlled impurity additions is necessary; single crystals of silicon of the required purity can be grown quite readily. Although much more is known about handling germanium than is known about silicon, the use of germanium does not result in an efficient device. In the case of the intermetallic compounds, the state of the art is much less advanced than even with silicon. Although some of the intermetallics, such as gallium arsenide, cadmium telluride, and indium phosphide would allow considerable gains in efficiency, much research is needed before practical devices could be produced. Most of the problems which must be surmounted at present are concerned with the investigations of physical and electrical properties of the materials themselves, such as purification, crystal growth, and obtaining fundamental electrical data on single crystals.

The advantages of semiconductor devices as solar energy convertors are quite obvious even though much research is required to perfect the devices. They are rugged, have no moving parts, are quite stable chemically when properly constructed, have a direct electrical output, and are being improved upon at a rapid rate.

Collecting Power from Large-Scale Solar-Energy Converters

Because of the low power level at which any of these systems would operate, a serious problem can be expected with large systems in gathering this energy and conveying it to a central point, such as a transmission line or a point of use.

In the case of one of the suggested photochemical processes, the "electrolyte" which has been mentioned would probably be relatively dilute. Large volumes of liquid might have to be handled over relatively long distances. For example, in the case of the 14-acre area mentioned for the 1000-kw station, the radius of a circular plot would be 400 ft; half the diagonal of a square plot would be 550 ft. For the photochemical process involving the production of hydrogen and oxygen, it is possible that large volumes of liquids might have to be handled over these distances, or the evolved gases would have to be collected at selected points and then transferred to a central point. The energy necessary for this mass transfer would, of course, constitute a loss from the system.

In the case of thermoelectric or photovoltaic cells, the electrical energy produced would be direct current at a low voltage. Although the cells might be connected in series to produce a useful potential, there would still be a problem through the losses in the electrical conductors. This might be minimized in some cases by using many small converters at different points in the collector system to produce alternating current from the direct current, and then using transformers to step up the voltage to reasonably high potentials.

This problem of transporting the energy from a wide expanse of solar collectors seems not to have been recognized, probably because most workers have been involved mainly in trying to devise workable devices where small-scale problems are serious enough. Nevertheless, the transport of energy within a large collection system might well be a determining factor in deciding on one system over another.

Storage of Energy

The importance of energy storage can scarcely be overemphasized. Although a few applications can be foreseen where solar-produced energy would be consumed as it was produced, in the long run some scheme of economical storage over night and during bad weather is certain to be necessary. Some of the processes suggested, such as that where hydrogen and oxygen are produced, stored in gaseous form, and then utilized in a fuel cell, appear reasonable if the process can be made to work. Fuel cells of the Bacon type have an efficiency high enough to arouse interest. Coupling them with hydrogen-oxygen producers working on solar energy seems to offer more promise than any scheme proposed thus far. A realistic appraisal is not possible yet, however, because so little is known about the feasibility of the solar converter.

The Future Outlook

At present, interest in solar energy is focused mainly on exploring fields in which power from the sun offers the most tempting possibilities. The recent rash of solar-powered electronic gadgets can be taken as one indication of the trend today. Although aware of the economic problems involved, most workers seem willing for the time being to consider cost as secondary to technical feasibility. This is not surprising, in light of the many fields in which solar energy might be used, the complexity and number of the technical problems to be solved, and the competition to be provided for many years by existing energy sources.

Nuclear fission, and fusion later, perhaps, certainly will exert a strong influence on the utilization of solar energy. Problems involving public health, reliability, availability, and even portability, can be expected to be decisive in fixing the future pattern of energy conversion. Where solar energy best fits into this pattern will be indefinite for many years to come.

Editor's Note:
The September 30, 1957 issue of the New York Herald Tribune carried a brief news story of the announcement by the Russian government of a solar energy plant they are planning that will produce 2,500,000 kwhr per year. The plant will employ a system of mirrors mounted on movable cars.

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

Statistical Mechanics

By Terrell L. Hill

McGraw-Hill Book Co., 432 pages, $9.00

This book, written for graduate students and research workers in theoretical chemistry and physics, summarizes the principles of statistical mechanics at an intermediate level, and presents an organized and detailed account of certain applications of statistical mechanics which have been worked out since about 1940.

The overall aim of the author in selecting these applications has been to report the most important recent advances that have occurred and to treat each of these in great detail, rather than to give a necessarily superficial account of every topic in the entire field. Emphasis is on the theory of the applications, not on numerical calculations for special cases. The principles are included primarily for completeness and to make the book self-contained. Many helpful appendices supplement the text.

Maintenance Engineering Handbook

By L. C. Morrow

McGraw-Hill Book Co., 1528 pages, $20.00

The long years of first-hand familiarity with the field of maintenance engineering gained by the author as chief editor of *Factory Management and Maintenance* and more recently as general chairman of the National Plant Maintenance and Engineering Conference is reflected in the selection of some 75 individual experts to cover various of the techniques, methods and procedures held by them to be most helpful in keeping production at maximum levels and yet exercising control over production costs and losses.

The bulk of the book is made up of information relative to the selection, installation, and upkeep of the kinds of equipment and services that plants must deal with; electrical, mechanical, and service equipment, transportation equipment, maintenance stores, instruments and instrumentation, and welding. In addition the author attempts to give the reader an insight into the management as well as operative phases of maintenance work—the principles of organization, training operators and supervisors, rating and evaluation of maintenance jobs, standard times for maintenance jobs, and cost control.

Manual on Industrial Water

ASTM Special Technical Publication No. 148-B, 502 pages, $6.00

This, the third and latest printing of the Manual on Industrial Water, is as always extremely welcome and a value to industry at large. Sponsored by ASTM Committee D-19 on Industrial Water, the Manual contains a complete appendix in addition to a comprehensive discussion of water, its uses, treatment, sampling, analysis and difficulties caused by it.

The appendix lists ASTM standards relating to industrial water. It contains five methods of sampling, 41 standards, four methods of analysis, three standards for methods of reporting results, six standards for methods of test, a glossary of terms, a list of industrial water requirements and a bibliography.

Included in the latest printing are seven new methods and one important revision. Two additional proposed methods are published as additional information. No changes have been made in the chapters of the Manual.

Corrosion: A Compilation

By Dr. Mars G. Fontana

Hollenback Press

Dr. Mars G. Fontana, chairman of the department of metallurgical engineering at Ohio State University, has authored a monthly column on corrosion during the past ten years for *Industrial and Engineering Chemistry*. This book is a compilation of those columns. The articles are grouped into seven chapters (1) Nature and Extent, (2) Eight Forms of Corrosion, (3) Eight Methods for Combatting Corrosion, (4) Corrosion Testing and Evaluation, (5) Materials, (6) Environments, and (7) High Temperature Oxidation.

Practically all metals and alloys and some non-metallics used for corrosion applications are covered. The book describes methods and detailed procedures for laboratory and plant testing, and shows corrosion as a function of temperature and concentraion of acids through iso-corrosion charts.

Causes and cures for many actual plant problems and mechanisms of corrosion are described in readily understandable terms.

Applied Metallurgy for Engineers

By Malcolm S. Burton

McGraw-Hill Book Co., 407 pages, $7.50

A prior knowledge of metallurgy is not required of the reader and the author follows this approach with a treatment essentially non-mathematical. Yet the book does provide, in a single volume, a combined coverage of physical metallurgy and industrial metallurgical processes presently available. Emphasis, though, is on the background of metallurgical science essential for proper utilization of metallurgical manufacturing methods. A good balance between theory and engineering practice is achieved; diagrams and photographs of equipment implement the theory and relate it to specific manufacturing methods.

The purpose of this book, according to the author, is twofold: to develop the metallurgical principles involved in casting, metal working, welding, heat treatment. and powder metallurgy; and to study these manufacturing processes from an engineering viewpoint, including the metallurgical factors that control selection of suitable processes and the influence of the processes on the final products so as to provide information valuable in school laboratory as well as larger production applications.

High Pressure Technology

By Edward W. Comings

McGraw-Hill Book Co., 572 pages, $11.50

This publication, one of McGraw-Hill's series in chemical engineering, is the first book to cover the whole field of high pressure technology, and to present the subject at a level that can be understood by a senior student of chemical engineering. Its author is professor of chemical engineering and head of the School of Chemical and Metallurgical Engineering, Purdue University. The central theme is the influence of elevated pressure on chemical and physical systems, and on the design of equipment for handling these systems experimentally or on a commercial scale. Extensive appendices supply data for problems, calculations, and design. A glossary of unusual words and terms is included.

This volume not only provides a reference and textbook for engineers and scientists who undertake industrial or laboratory work at high pressure, but also provides the chemical engineering

student with a means of integrating much of the early course work and focusing both the science and the art on the limited field of the applications which involve high pressure. After an introductory chapter, a number of chemical processes are listed and described briefly by R. Norris Shreve to point out the applications of the other chapters. Following this, H. C. Van Ness contributes an introduction to the principles governing the properties of metals, which provides a basis for the selection and treatment of metals and alloys for use in high pressure equipment. Subsequent chapters deal with principles of design and such help as procedures and suggestions for safe practices.

Pump Selection and Application

By Tyler G. Hicks

McGraw-Hill Book Co., 432 pages, $8.50

A very thorough and well organized discourse on the basic types of pumps and problems met in their application is the outstanding feature of this book. The author has devoted a chapter to each of a number of industries and their pump problems. These include powerplant services, nuclear-energy applications, petroleum, chemicals, paper, textiles, rubber, food, water supply, sewage, air conditioning, heating, irrigation, flood control, mining, construction, marine, hydraulic, iron and steel.

Some special topics are covered such as pumping-system economic analyses, pump specifications, comprehensive analyses of the pumping requirements for a variety of industries, major discussions of pump head, liquid handled.

Properties of Wrought Medium-Carbon Alloy Steels

ASTM Special Technical Publication No. 199, 127 pages, $4.25

The increasing demand for metals at high temperatures prompted an investigation of the elevated temperature properties of wrought medium-carbon alloy steels. This report, one of a series, is based on data compiled and issued under the auspices of the data and publications panel of the ASTM-ASM Joint Committee on the Effect of Temperature on the Properties of Metals. It gives a graphical summary of the elevated-temperature strength data for medium-carbon alloy steels, includes summary curves for tensile strength; 0.2 per cent offset yield strength; per cent elongation and reduction in area; stresses for rupture in 100, 1000, 10,000, and 100,000 hr; and stresses for creep rates of 0.0001 and 0.00001 per cent per hour (one per cent in 10,000 and 100,000 hr). Data for 27 steels representing

approximately a dozen alloy traps are given. The report also contains data for a few miscellaneous low-carbon alloy steels.

Research and Development Summary

National Bureau of Standards Miscellaneous Publication 220, 158 pages, 60c

This report, the Annual of the National Bureau of Standards for 1956, summarizes the research and development activities of the National Bureau of Standards in the physical sciences during the fiscal year 1956. Brief descriptions are given of representative accomplishments in each area of the Bureau's responsibilities, which include maintenance of basic standards, determination of physical constants and properties of matter, development of methods and instruments of measurement, and the provision of calibration, testing and scientific advisory services.

The Annual Report is composed of five sections: (1) a general review or summary, (2) a résumé of the Bureau's research and development work in progress or completed in 1956, (3) a review of the testing and calibration program, (4) a discussion of the Bureau's various cooperative activities, and (5) an appendix consisting primarily of statistical and organizational material and a complete list of publications by NBS staff members for the fiscal year.

Nuclear Power Engineering

By Henry C. Schwenk and Robert H. Shannon

Edited by B. G. A. Skrotzki

McGraw-Hill Book Co., 344 pages, $6.50

Planned for engineers, technicians, and executives concerned with practical power development this book is based upon a series by the same team appearing in *Power* as a study course from July of 1954 on. It gives an explanation of nuclear power plants—design, construction, and operation in one volume. Certain essential fundamentals of physics plus detailed design features of specific power reactors are covered. In addition to engineering methods, information is advanced on the components of various systems as well as various sundry items such as radiation and its effects on equipment and health, plant sites, economics of nuclear power production, other pertinent topics.

Engineering Thermodynamics

By C. O. Mackey, W. N. Barnard, F. O. Ellenwood

John Wiley & Sons, 428 pages, $7.95

This book is an outgrowth of Heat-Power Engineering by W. N. Barnard, F. O. Ellenwood and C. F. Hirshfeld. The third edition of that eminent publication was completely rewritten by Ellenwood and Barnard. Part I, you may recall, was published in 1926 and Parts II and III in 1933. The three covered the gamut of engineering thermodynamics—steam generating apparatus, prime movers, fuels, combustion, fluid flow, heat transmission, air conditioning and refrigeration. Mr. Mackey, however, well aware of the wide use and careful work that had been enjoyed by these volumes, nevertheless felt that the boundaries of power and heat engineering had so expanded in the last decade that a rewrite was in order, rather than a revision.

Further as Mr. Mackey states there appears to be a growing trend to drop from engineering curricula, except at advanced or elective levels, the so-called "applied" courses, like combustion engines, steam power plants, refrigeration and air conditioning. So it became mandatory to teach more applied thermodynamics in the courses. This book, then, has been written for the student with the usual prerequisites of mathematics, physics, chemistry and mechanics. It is written for the serious student who expects to make a profession of engineering and, in our opinion, does not disappoint its intended audience.

Modern Chemistry for the Engineer and Scientist

Edited by G. Ross Robertson

McGraw-Hill Book Co., 442 pages, $9.50

The University of California has developed a series of highly successful engineering extension lecture courses aimed at the graduate in physical sciences, perhaps a decade or so beyond his graduation, interested in some specially chosen field of activity. The series of courses in chemistry in the year 1954–1955 following the well received ones in physics and mathematics comprise the subject matter for this volume.

Nineteen nationally known chemists, both academic and industrial, presented lectures on their specialties. These lectures may well be recognized as being sighted at a level well above that of many of the audience but they were presented deliberately so on the same grounds that the industrious freshman suffers no harm when he listens to the Nobel laureate addressing his department's seminar on his special topic. The individual chapters will, we believe, prove most stimulating to those specialists who have lost touch somewhat with general progress in their field of interest and prove most informative to those whose activities have led them away from their undergraduate specialties.

National Plumbing Code Handbook

Edited by Vincent T. Manas, consulting engineer

McGraw-Hill Book Co., 544 pages, $7.50

Plumbers and others concerned with the specifications, performance, and inspection of plumbing installations are offered a clear, simple guide to the National Plumbing Code in this new book based on the Code ASA A40.8. The handbook explains and illustrates the meaning and intent of the Code, paragraph by paragraph, and includes related technical information and data to aid in the design and installation of plumbing, water supply, sewage, and drainage systems that will meet Code requirements.

The entire Code is covered in Parts I and II of the book. Each paragraph of the Code is quoted and then explained in nontechnical language. Part III is devoted to technical studies and standards related to the principles of pneumatics and hydraulics embraced in a plumbing system.

The Code was designated as an American Standard by the American Standards Association in January, 1955. It has already been adopted as official by 30 states and numerous municipalities, and probably will serve as the basis of formulation for many local codes. There are certain other chapters relating to research and some special technical material. This material is the contribution of Herbert N. Eaton, formerly chief, Hydraulics Laboratories, National Bureau of Standards.

Air Pollution Handbook

By Paul L. Magill, Francis R. Holden, Charles Ackley

McGraw-Hill Book Co., 681 pages, $7.75

In the preface to this Handbook the editors state: "In short, a book is needed which bridges the gaps between the various disciplines involved, and between these disciplines and interested laymen such as city planners and industrialists. A book is needed which provides basic source material on the many facets of air pollution. Such are the purposes of this book."

With such an admittedly wide range of interests and disciplines the editors adopted a frequent technique in the compilation of a Handbook, namely, they sought a number of authorities in specific fields to author individual chapters.—The result was some thirty are authors for a 14-section book. Certain of the contributions are excellent, broadly treated, well presented with fine supporting bibliographies. Others we felt were somewhat abstract and of questionable value to the audience the book envisions, "interested laymen such as city planners and industrialists." In the main the Handbook is a worthy addition to the professional air pollution control authority's library.

Symposium on Steam Quality

ASTM Special Technical Publication No. 192, 49 pages, $.175

The Joint Research Committee on Boiler Feedwater Studies sponsored a special symposium to review present practices and introduce new techniques

for obtaining information on steam purity for use in modern steam generators. With the introduction of higher pressures and higher steam temperatures causing vaporization of dissolved solids, the Symposium felt a need for more sensitive and accurate measurement. Consideration of these problems is made in this symposium. Among the items covered are: Measurement and Purification of Steam to 0.01 ppm Total Dissolved Solids—W. B. Gurney, Steam Purity Determination by Tracer Techniques—E. E. Coulter and T. M. Campbell, Comments on Corrections to Steam Conductivity Measurements—R. O. Parker and R. J. Ziobro, Construction and Operation of Larson-Lane Steam Purity and Condensate Analyzers—A. B. Sisson, F. G. Straub and R. W. Lane.

The volume contains extensive mathematical material and should be of interest to power engineers, water chemists and scientists and technicians in related fields.

Symposium on pH Measurement

ASTM Special Technical Publication No. 190, 104 pages, $2.50

During the ten years which have elapsed since ASTM published the first Symposium on pH Measurement, significant developments in the field have occurred. To keep pace with these advances with pH instrumentation and technology, a second symposium was organized and published in this volume.

Among the topics covered are: Meaning and Standardization of pH Measurements—R. G. Bates, Performance Studies of Reference-Electrodes and Their Components at High-Temperatures and Pressures—J. E. Leonard, Modern Developments in pH Instrumentation—W. R. Clark and G. A. Perley, Problems in Measurement of pH of Blood and Other Biological Fluids—Julius Sendroy, Jr., Quantitative Applications of pH Measurements in Analytical Chemistry—Henry Frieser, Theoretical and Practical Problems in the Measurement of Acidity in Nonaqueous Media—Martin Kilpatrick, Indicator Acidity Functions for Nonaqueous and Mixed Solvents—M. A. Paul and F. A. Long.

The Symposium covers such developments as nonaqueous solutions and refined methods of instrumentation, and considers them not solely as advances in themselves but also as creating special problems all their own. The publication is well illustrated and contains several extensive bibliographies.

The publication constitutes an excellent reference on the latest practices and in addition reflects the thinking of the individuals most likely to influence future practice.

Reactors

By R. A. Charpie, D. J. Hughes, M. Trocheris

McGraw-Hill Book Co., 592 pages, $14.00

This particular volume, Series II of the publishing company's Progress in Nuclear Energy series, in essence is a series of review papers on the present state of the reactor art. The editors, all eminently qualified to pass upon an individual paper's worthiness, are backed up by an extremely rich editorial advisory board which numbers experts from almost all the prominent nuclear study installations in the Western World.

L. R. Hafstad, now vice president in charge of research for General Motors Corp. and before that director of reactor development for the AEC, stated in the preface "The papers in this volume are of the greatest importance, for they cover the basic subject of reactors. . . It is the development of such reactors which culminated over fifty years of discoveries in the physics of the atom. It is the further development of the reactor and its applications that will make atomic energy available to our power-demanding economies. This volume will be a classic in its field and will be looked upon as the first truly international text on the subject."

In closing this volume has been said to contain the meat of the new material released from declassification at the Geneva Conference. All in all this publication merits readership by all serious students of nuclear energy.

Mechanical Engineering Laboratory

By Jesse Seymour Doolittle

McGraw-Hill Book Co., 396 pages, $6.50

This text has been written primarily for the college student taking his first courses in a mechanical engineering laboratory. It is aimed at acquainting the student with the various types of instruments for making measurements of the quantities most frequently employed in mechanical engineering work and study. The material is certainly helpful and valuable background data for all laboratory courses and should prove equally worthwhile for any in industry, graduate engineer or not, who needs basic instruction in laboratory equipment. We could see it as a training aid for laboratory technicians.

The use and limitations of instruments are given and certain stress is made of the care required in installing instruments and obtaining the correct measurements. Some work has been included on use of test codes, specifically on the properties of fuels and lubricants.

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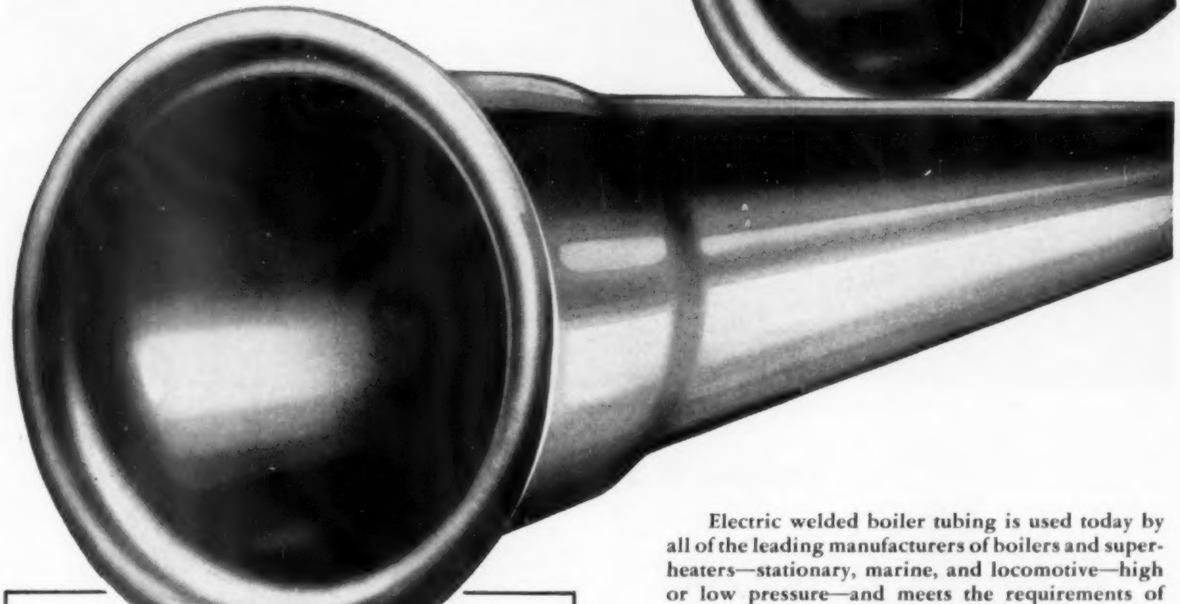

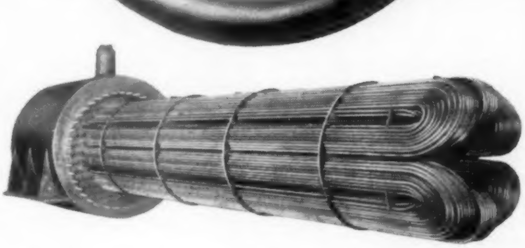

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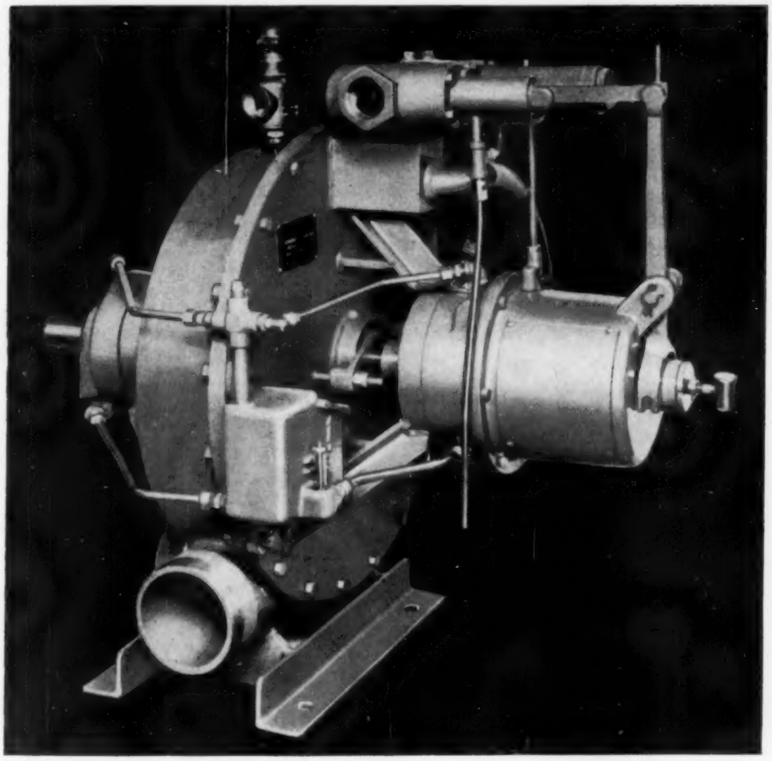
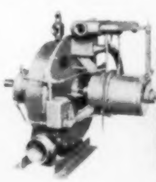
(Continued on page 71)





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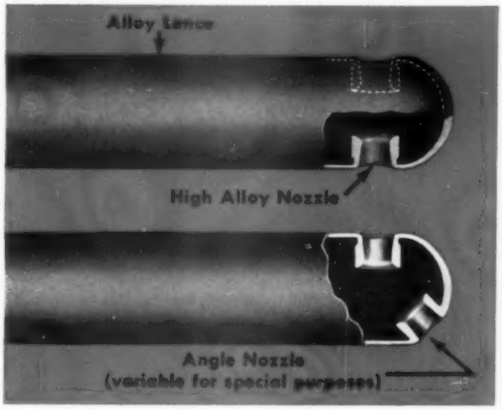
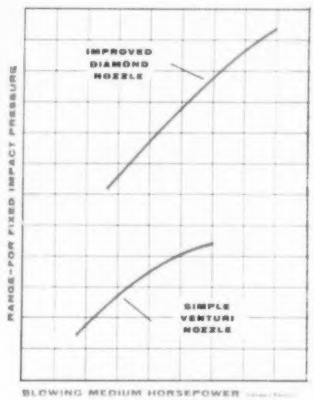
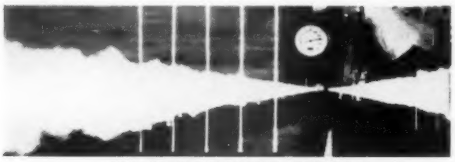
This feature is one of many reasons why the Diamond Series 300 IK Blower does a better and more economical job of cleaning surfaces which require a long retracting blower. Other advantages are listed at the bottom of the page. Ask the nearest Diamond office or write directly to Lancaster for Bulletin 2111V which will tell you much more about the new Series 300 IK.

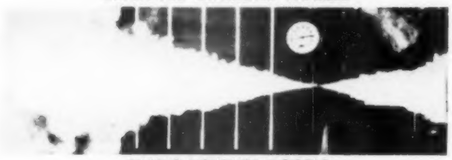


Improved Diamond Type "A" Nozzle has low approach velocity for optimum nozzle performance (see curves below). It provides greatest impact for any given blowing pressure . . . means greater effectiveness and economy.





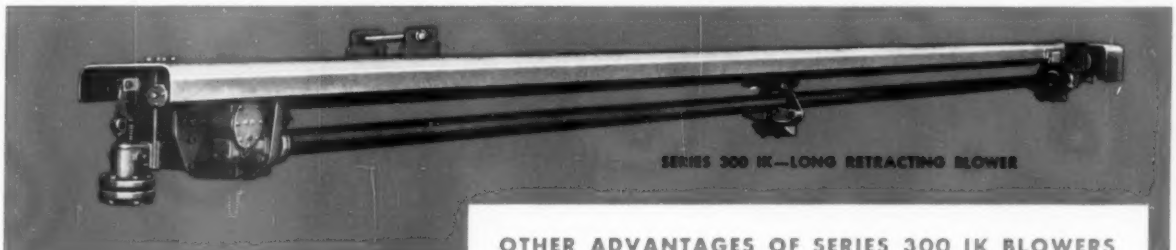
IMPROVED DIAMOND NOZZLE



SIMPLE VENTURI NOZZLE

Note the greater blowing range of the improved Diamond Nozzle when compared with a simple venturi nozzle under identical test conditions.

7859



OTHER ADVANTAGES OF SERIES 300 IK BLOWERS

- Backbone and Protective Cover
- Front End Single-Motor Drive
- Compact, Accessible Electric Power and Control Terminal Facilities
- Positive Gear Carriage Drive
- Poppet Valve with Adjustable Pressure Control
- Positive Mechanically Operated Valve
- Improved Cleaning Pattern
- Single Point Outboard Suspension
- Oversize Lance (Step-Tapered for Extra Long Travel)
- Auxiliary Carriages for Extra Long Travel
- Designed for Quick, Easy Servicing

No other blower gives you all these advantages.

DIAMOND POWER SPECIALTY CORP.
LANCASTER, OHIO

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